AFMC

KEEPING THE EDGE

Air Force Materiel Command Cold War Context (1945-1991)

Volume II:
Installations and Facilities

Karen J. Weitze

Developing, Fielding, and Sustaining America's Air and Space Force

KEEPING THE EDGE

Air Force Materiel Command Cold War Context (1945-1991)

VOLUME I
Command Lineage, Scientific Achievement, and Major Tenant Missions

VOLUME II
Installations and Facilities

VOLUME III
Index

For copies, contact:

Cultural Resources Manager
HQ AFMC/CEVQ
4225 Logistics Avenue, Room A-128
Wright-Patterson AFB OH 45433-5747

Phone: DSN 986-1281 or 787-7414
COMM 937-656-1281 or 937-257-7414

Also posted in pdf format at the Air Combat Command public web site: http://www.cevp.com.

KEEPING THE EDGE

Air Force Materiel Command Cold War Context (1945-1991)

VOLUME II:
Installations and Facilities

Headquarters Air Force Materiel Command
Wright-Patterson Air Force Base, Ohio

United States Air Force
United States Department of Defense

Karen J. Weitze

EDAW, Inc.
through Prewitt and Associates, Inc.
Contract DACA-63-95-D-0051, Delivery Order 0044
United States Army Corps of Engineers, Fort Worth District

August 2003

Table of Contents: All Volumes

The table of contents for the full three-volume set is included below. A boldface volume reference indicates the volume herein.

Volume I: Command Lineage, Scientific Achievement, and Major Tenant Missions

Volume II: Installations and Facilities

List of Plates

Preface

Installations and Facilities is Volume II of the three-volume contextual history *Keeping the Edge: Air Force Materiel Command Cold War Context (1945-1991)*. Its companion, *Command Lineage, Scientific Achievement, and Major Tenant Missions* is Volume I. The third volume in the set is a stand-alone index for Volumes I and II. *Keeping the Edge* covers the 45-year period from 1945 to 1989 / 1991. The study functions both as traditional military history, and as a historic context for assessing buildings and structures extant at installations reporting to Headquarters Air Force Materiel Command at the time of the study (1999-2003). In order to fulfill its role as a historic context, *Keeping the Edge* includes detailed information on the history of infrastructure and civil engineering achievements across the command. The author has highlighted key architectural-engineering firms and has endeavored to place their work for Air Force Materiel Command in perspective with other military and civilian commissions of the Cold War. *Keeping the Edge* also contains many rare photographs. For the majority of the primary records, the author relied on the collections of the Air Force Historical Research Agency at Maxwell and those at the National Archives II in suburban Washington, D.C. She, or an assistant, also visited the installations within Air Force Materiel Command. At the bases and industrial plant sites, the history offices participated in the project, as did the cultural resource offices and civil engineering (drawings) vaults. The author assessed a wide range of buildings and structures at the bases and compared these to the information available in the records. Selected oral interviews supported the research. The acknowledgments, introduction (goals and methodology), and summary sections for *Keeping the Edge* appear only in Volume I, while acronyms lists and bibliographies are provided particular to each volume. Many base photographs appear in the broader discussions of Parts I-IV of Volume I. The author has cross-referenced these in the chapters of Volume II, as appropriate.

Volume II, *Installations and Facilities*, is organized primarily by the installations and industrial plants that reported to Air Force Materiel Command in 1999-2000. Discussion of the bases appears first, with each installation encapsulated in an independent chapter. The Air Force has closed or realigned two bases, Kelly and McClellan, while the study was in progress. In addition, in 2002 the Air Force reassigned another base, Los Angeles, from Air Force Materiel Command to Air Force Space Command and finished privatizing Brooks Air Force Base. These four chapters remain in the current work. Volume II presents the four Air Force Plants (AFPs) together in the final chapter. The discussed AFPs include AFP 4 in Fort Worth, Texas; AFP 6 in Marietta, Georgia; AFP 42 in Palmdale, California; and, AFP 44 in Tucson, Arizona. An analysis of the larger Air Force industrial plant program of the Cold War is included in Part II of Volume I. A look at major tenant missions across the bases, such as Strategic Air Command alert, is reviewed in the chapters, but substantially appears in Part IV of Volume I. The 15 chapters of Volume II are:

Chapter 1	Arnold Air Force Base
Chapter 2	Brooks Air Force Base
Chapter 3	Edwards Air Force Base
Chapter 4	Eglin Air Force Base
Chapter 5	Hanscom Air Force Base
Chapter 6	Hill Air Force Base
Chapter 7	Kelly Air Force Base
Chapter 8	Kirtland Air Force Base
Chapter 9	Los Angeles Air Force Base
Chapter 10	McClellan Air Force Base
Chapter 11	Robins Air Force Base
Chapter 12	Rome Research Site
Chapter 13	Tinker Air Force Base
Chapter 14	Wright-Patterson Air Force Base
Chapter 15	Air Force Industrial Plants

List of Acronyms

A	attack / amphibian (in an aircraft designation)
AAF	Army Air Forces
ABC	atomic, biological, and chemical
ABCCC	Airborne Battlefield Command and Control Center
ABM	antiballistic missile
ABRES	Advanced Ballistic Reentry Systems
A/C	aircraft (in hangar designations)
AC	attack cargo (in an aircraft designation)
ACAD	Automotive Committee for Air Defense
AC&W	Aircraft Control & Warning
ACCS	Airborne Command and Control Squadron
ACHILLES	AFWL Characterization Interim Low Level EMP Simulator
AD	attack Douglas (in an aircraft designation)
ADAR	Advanced Design Array Radar
ADC	Aerospace Defense Command; Air Defense Command
ADCA	Air Depot Control Area
ADCC	Air Defense Control Center
ADDC	Air Defense Direction Center
ADES	Air Defense Engineering Service
ADG	Air Depot Group
ADIS	Air Defense Integrated System
ADSEC	Air Defense Systems Engineering Committee
ADSID	Air Defense Systems Integration Division
ADSMO	Air Defense Systems Management Office
AEC	Atomic Energy Commission
AEDC	Air Engineering Development Center; Arnold Engineering Development Center
AEDD	Air Engineering Development Division
AEW&C	Airborne Early Warning and Control
AF	Air Force
AFAC	Air Force Armament Center
AFB	Air Force Base
AFBMD	Air Force Ballistic Missile Division
AFCC	Air Force Communications Command
AFCCDD	Air Force Command and Control Development Division
AFCRC	Air Force Cambridge Research Center
AFDTC	Air Force Development and Test Center
AFLC	Air Force Logistics Command
AFMC	Air Force Materiel Command
AFOAT	Air Force Office of Atomic Energy
AFOTC	Air Force Operational Test Center
AFP	Air Force Plant
AFRL	Air Force Research Laboratory
AFRTC	Air Force Reserve Training Center
AFSC	Air Force Systems Command
AFSCF	Air Force Satellite Control Facility
AFSPC	Air Force Space Command
AFSWP	Armed Forces Special Weapons Project
AFWAL	Air Force Wright Aeronautical Laboratory

AFWL	Air Force Weapons Laboratory
AGARD	Advisory Group for Aeronautical Research and Development
AGCA	Automatic GCA
AGM	air-launched, ground-attack missile; air-to-ground missile
AIA	Air Intelligence Agency
AID	Aircraft Intercept Direction
AIM	air interceptor missile
ALARR	air-launched, air-recoverable rocket
ALC	Air Logistics Center
ALCM	air-launched cruise missile
ALCO	American Locomotive Company
ALCS	Airborne Launch Control System
ALECS	AFWL / Los Alamos Scientific Laboratory EMP Calibration and Simulation
ALL	Airborne Laser Laboratory
ALRI	Airborne Long Range Input
AMA	Air Materiel Area
AMC	Air Materiel Command
AMRAAM	advanced medium range air-to-air missile
A/N	Army / Navy
AN/	Army-Navy (in radar and electronics equipment designations)
ANG	Air National Guard
ANMB	Army-Navy Munitions Board
ANP	Aircraft Nuclear Propulsion
AOC	Air Operations Center
APN	airborne / radar / navigational aid (in radar and electronics equipment designations)
APPR	Army Package Power Reactor
ARDC	Air Research and Development Command
ARES	Advanced Radiation EMP Simulator (alternately known as Advanced Research EMP Simulator and AFWL / RAND EMP Simulator)
ARIA	Apollo Range Instrumentation Aircraft
ARL	Aerospace Research Laboratories
ARM	antiradiation missile
ARMCO	American Rolling Mills Company
ARO	Arnold Research Organization
ARPA	Advanced Research Projects Agency
ART	Advanced Radiation Technology
ASACS	Airborne Surveillance and Control System
ASALM	advanced strategic air-launched missile
ASAT	Anti-Satellite [Program]
ASD	Aeronautical Systems Division
ASTF	Aeropropulsion Systems Test Facility
AT	advanced trainer (in an aircraft designation)
ATC	Air Training Command
ATHAMAS	AFWL Terrestrial High-Altitude EMP Alert Mode Aircraft Simulator
ATLAS	AFWL Transmission Line Aircraft Simulator
AVLAB	Science Laboratory, Avionics (at Wright-Patterson Air Force Base)
AWAC	Airborne Warning and Control
AWACS	Airborne Warning and Control System
AX	attack experimental (in an aircraft designation)

Azon	azimuth only
B	bomber (in an aircraft designation)
BART	Bay Area Rapid Transit
BDR	bomb-damage repair
BEEF	[Prime] Base Engineering Emergency Force
BEET	Base Engineer Emergency Test
BEMI-AA	Base Engineering Maintenance and Inspection – Army Air Forces
BGM	ballistic guided missile
BLC	Boundary Layer Control
BMEWS	Ballistic Missile Early Warning System
BMW	Bavarian Motor Works
Bomarc	Boeing Michigan Aeronautical Research Center
BRAC	Base Realignment and Closure
BRL	Ballistic Research Laboratories
BUIC	Back-Up Interceptor Control
BW	biological warfare
C	Centigrade; cargo (in an aircraft designation)
C-4	a plastic explosive using cyclotrimethylene trinitramine (90% by weight)
C^4I	command, control, communications, computers, and intelligence
CA	California
CAA	Civil Aeronautics (Authority) Association
CANEL	Connecticut Aircraft Nuclear Engine Laboratory
CAT	Computerized Axial Tomography
CBS	Columbia Broadcasting System
CDS	Comprehensive Display System
CEBMCO	Corps of Engineers Ballistic Missile Construction Office
CERF	Civil Engineering Research Facility
CIST	Cylindrical In-Situ Tests
COIL	Chemical Oxygen-Iodine Laser
CONAC	Continental Air Command
CONAD	Continental Air Defense Command
CPN	air-transportable / radar / navigational aid (in radar and electronics equipment designations)
CPS	air-transportable / radar / detection (in radar and electronics equipment designations)
CRD	air-transportable / radio / direction finder (in radar and electronics equipment designations)
CRT	cathode-ray-tube
CW	chemical warfare; continuous wave; Curtiss-Wright; air-transportable control device (in radar and electronics equipment designations)
DASA	Defense Atomic Support Agency
DASIAC	Defense Atomic Support Information Activity Center
db	decibels
DC	double-cantilever [hangar]
DEW	Distant Early Warning
DH	demountable hangar
DIHEST	Direct-Induced High Explosive Simulation Technique
DIP	DIHEST Improvement Program
DMJM	Daniel, Mann, Johnson, and Mendenhall
DNA	Defense Nuclear Agency
DOD	Department of Defense

DOE	Department of Energy
DRR	Digital Relay Radar
DSCS	Defense Satellite Communications System
DSP	Defense Support Program
DTRA	Defense Threat Reduction Agency
DTRIAC	Defense Threat Reduction Information Analysis Center
DU	depleted uranium
DVL	Deutsche Vesuchsanstalt für Luftfahrt
E	electronic [radar] (in an aircraft designation)
EADF	Eastern Air Defense Force
EC	electronic [radar] cargo (in an aircraft designation)
ECCM	electronic counter-countermeasures
ECM	electronic countermeasures
EF	electronic [radar] fighter (in an aircraft designation)
EG&G	Edgerton, Germeshausen & Grier
EGTR	Eglin Gulf Test Range
EMP	electromagnetic pulse
EMPTAC	EMP Test Aircraft
EOD	Explosive Ordnance Disposal
ESAR	Electronically Scanned Array Radar
ESC	Electronic Systems Center
ESD	Electronic Systems Division
ESS	Experimental SAGE Sector
ETF	Engine Test Facility
ETRB	Engineering Test Reactor Building
F	fighter (in an aircraft designation)
FAA	Federal Aviation Administration
FAID	Fairfield Air Intermediate Depot
FB	fighter bomber (in an aircraft designation)
FEMCOR	Field Emission Corporation
FFAR	folding-fin air-to-air rocket
FIS	Fighter-Interceptor Squadron
FOUO	For Official Use Only
FPN	fixed / radar / navigational aid (in radar and electronics equipment designations)
FPS	fixed / radar / detection (in radar and electronics equipment designations)
FRC	fixed / radio / passive receiving (in radar and electronics equipment designations)
FSQ	fixed / special equipment / special purpose (in radar and electronics equipment designations)
FX	Flash X-ray
FY	Fiscal Year
G	gravity (gravitational force)
GALCIT	Guggenheim Aeronautical Laboratory at the California Institute of Technology
GAM	guided air missile
GAP	Government Aircraft Plant
Gapa	ground-to-air pilotless aircraft
GAR	guided air rocket
GB	sarin gas
GCA	Ground Controlled Approach
GCI	Ground Control Intercept / Interception
GDF	Gas Dynamics Facility
GEEIA	Ground Electronics Engineering Installation Agency

GLCM	ground-launched cruise missile
GOCO	government-owned, contractor-operated
GPS	Global Positioning System
GQ	General Quarters
GRA	general ground use / radio / *unknown* (in radar and electronics equipment designations)
GRABS	Giant Reusable Airblast Simulator
GRC	general ground use / radio / communications (in radar and electronics equipment designations)
GRD	general ground use / radio / direction finder (in radar and electronics equipment designations)
GSU	geographically separate unit
GWEN	Ground Wave Emergency Network
HABS	Historic American Buildings Survey
HAER	Historic American Engineering Research
HANG-N-A	hangar Navy Army (?)
HDP	Horizontal Dipole Simulator
HERTF	High Energy Research and Technology Facility
HEST	High Explosive Simulation Technique
HETF	Hill Engineering Test Facility
HF	high frequency
HLRB	High Level Radiation Building
hp	horse power
HPS	Horizontally Polarized Simulator
HR	House of Representatives
HVAR	high velocity aircraft rocket
IBM	International Business Machines
ICBM	intercontinental ballistic missile
IDECO	International Derrick and Equipment Company
IEEE	Institute of Electrical and Electronics Engineers
IFF	identification friend-or-foe
IHARDS	Improved High-Altitude Radiation Detection System
IIT	Illinois Institute of Technology
IM	interceptor missile
INEEL	Idaho National Engineering and Environmental Laboratory
INF	Intermediate-Range Nuclear Forces [Treaty]
IRAN	Inspection and Repair as Necessary
IRBM	intermediate range ballistic missile
IUS	inertial upper stage
JATO	jet-assisted takeoff
JB	jet bomb
JOC	Joint Operations Center
JPL	Jet Propulsion Laboratory
JRDB	Joint Research and Development Board
JSS	Joint Surveillance System
JTIDS	Joint Tactical Information Distribution System
KC	tanker cargo (in an aircraft designation)
keV	kiloelectron volt
L	liaison (in an aircraft designation)
LASA	Large Aperture Seismic Array
LF	linear feet

LFM	Luftfahrtforschungsanstalt München
LGM	silo-launched, surface-attack guided missile
LITR-ORR	Low Intensity Test Reactor – Oak Ridge Research Reactor
LORAN	Long-Range Radio Navigation
LOX	liquid oxygen
MAC	Military Airlift Command
MAP	Multiple Aim Point
MATS	Military Air Transport Service
MB	medium bomber / missile bomber (?)
MBA	Masters in Business Administration
MCP	Military Construction Program
MD	Maryland
MeV	megaelectron volt
MEW	Microwave Early Warning
MIDAS	Missile Detection Alarm System
MiG	Mikoyan Gurevich
MILSTAR	Military Strategic Tactical and Relay Satellite System
MIRV	multiple independently targetable reentry vehicles
MIT	Massachusetts Institute of Technology
Mk	Mark
MNRC	McClellan Nuclear Radiation Center
MNRS	Maneuverable Neutron Radiography System
MOL	Manned Orbiting Laboratory
MPN	mobile, ground use / radar / navigational aid (in radar and electronics equipment designations)
MPS	Multiple Protective Shelter; mobile, ground use / radar / detection (in radar and electronics equipment designations)
MRBM	medium range ballistic missile
MSQ	mobile, ground use / special equipment / special purpose (in radar and electronics equipment designations)
MULDAR	*unknown*
MX	missile experiment (experimental)
MXRS	Maneuverable X-ray Radiography System
N	Northrop; special test (in an aircraft designation)
NACA	National Advisory Committee for Aeronautics
NARF	Nuclear Aerospace Research Facility
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVSTAR	Navigation System using Training and Ranging
NB	special test bomber (in an aircraft designation)
NCC	NORAD Control Center
NCO	Non-Commissioned Officer
NDI	Non-Destructive Inspection
NDRC	National Defense Research Committee
NEACP	National Emergency Airborne Command Post
NEADS	Northeast Air Defense Sector
NELB	Nuclear Engineering Laboratory Building
NEPA	Nuclear Energy for the Propulsion of Aircraft
NETF	Nuclear Engineering Test Facility
NKC	a tanker (KC) loaded with special equipment (N) by AFSC (in an aircraft designation)

NMERI	New Mexico Engineering Research Institute
NORAD	North American Air Defense Command
NPA	Nuclear Propulsion Aircraft
NRTS	National Reactor Testing Station
NSRC	National Supersonic Research Center
NSS	National Storage Site
NTA	Nuclear Test Aircraft
NUDETS	Nuclear Detonation Detection and Reporting System
NYA	National Youth Administration
O	Operations
OAR	Office of Aerospace Research
OCAMA	Oklahoma City Air Materiel Area
OOAMA	Ogden Air Materiel Area
Ops C	Operations Combat
Ops D	Operations Direction
ORDCIT	Ordnance Department at the California Institute of Technology
ORNL	Oak Ridge National Laboratories
OSRD	Office of Scientific Research and Development
OSS	Operational Storage Site
OST	Operational Suitability Test
OTH	Over-the-Horizon
OTH-B	Over-the-Horizon Backscatter
P	pursuit (in an aircraft designation)
PACCS	Post-Attack Command Control System
PACE	Pacific Cratering Experiment
PAVE PAWS	Perimeter Acquisition Vehicle Entry Phased Array Warning System
PBS	Public Buildings Service
PETN	pentaerythritoltetranitrate
P&H	power and heating
POW	prisoner of war
PPI	plan position indicator
PQ	pursuit drone (in an aircraft designation)
PRAM	Productivity, Reliability, Availability, and Maintainability [Project]
psi	pounds per square inch
PWT	Propulsion Wind Tunnel
Q	drone (in an aircraft / missile designation); AEC / DOE security clearance
QB	drone bomber (in an aircraft designation)
R	rotary wing (in an aircraft designation, later becoming H for helicopter)
RADC	Rome Air Development Center
RAF	[British] Royal Air Force
RAM	Random Access [core] Memory; Rapid Area Maintenance
RAND	[Douglas] Research and Development
RASS	Rapid Area Supply Support
rawinsonde	radar wind sounding
Razon	radio and azimuth only
RB	reconnaissance bomber (in an aircraft designation)
RC	reconnaissance cargo (in an aircraft designation)
RCA	Radio Corporation of America
RCS	radar cross section
R&D	research and development
Red Horse	Rapid Engineer Deployable Heavy Operations Repair Squadrons, Engineering

RES	Radiating EMP Simulator
RF	radio frequency
RFML	Rapid Fire Multiple Launch
ROAMA	Rome Air Materiel Area
ROCC	Region Operations Control Center
RP	reconnaissance pursuit (in an aircraft designation)
RTD	Research Test Directorate
RTF	Rocket Test Facility
RTV	reentry test vehicle; remotely piloted test vehicle
S	storage
SAAMA	San Antonio Air Materiel Area
SAB	Scientific Advisory Board
SAC	Strategic Air Command
SAG	Scientific Advisory Group
SAGCI	Semi-Automatic Ground Control Intercept
SAGE	Semi-Automatic Ground Environment
SAIC	Science Applications International Corporation
SALT	Strategic Arms Limitation Talks [treaty]
SAM	surface-to-air missile
SAMA	Sacramento AMA
SAM-CRT	Special Air Mission – Combat Readiness Training
SAMOS	Satellite and Missile Observation System
SAMSO	Space and Missile Systems Organization
SAMTO	Space and Missile Systems Test Organization
SARAC	Steerable Array Radar and Communications
SATCOM	Satellite Communications System
SBAMA	San Bernardino Air Materiel Command
SC	search and rescue cargo (in an aircraft designation)
SCA	Southern Communications Area
SCAD	subsonic cruise armed decoy
SCR	Signal Corps Radio (in early radar equipment designations)
Scram	supersonic combustion ram (jet)
SDI	Strategic Defense Initiative (Star Wars)
SEA	Southeast Asia
SESP	Space Experiments Support Program
SH	search and rescue helicopter (in an aircraft designation)
SICBM	small intercontinental ballistic missile
SIEGE	Simulated EMP Ground Environment
SLBM	sea (submarine) -launched ballistic missile
SM	strategic missile
SMAMA	Sacramento Air Materiel Area
SMART	Supersonic Military Air Research Track
SNAP	System for Nuclear Auxiliary Power
SNORT	Supersonic Naval Ordnance Research Track
SNRS	Stationary Neutron Radiograph System
SOCC	Sector Operations Control Center
SOR	Source of Repair
SPADATS	Space Detection and Tracking System
SPQ	shipboard / radar / special purpose (in radar and electronics equipment designations)
SR	strategic reconnaissance (in an aircraft designation)

SRA	Specialized Repair Activity
SRAM	short-range attack missile
SSTTP	Safeguard System Test Targets Program
STARS	[Joint] Surveillance Target Attack Radar System
START	Strategic Arms Reduction Treaty
STOL	Short Take-Off and Landing
STP	Space Test Program
T	trainer (in an aircraft designation); technical (T-system); temporary (building designation)
TAB VEE	Theater Base Vulnerability
TAC	Tactical Air Command; Tactical Air Control
TACAMO	Take Charge and Move Out
TACC	Tactical Air Control Center
TADC	Tactical Air Direction Center
TDY	temporary duty assignment
TIROS	Television Infrared Observation Satellite
TM	tactical missile
TN	thermonuclear
TNT	trinitrotoluene
TORUS	Transient Omnidirectional Radiating Unidistant and Static
TOW	tube-launched, optically-tracked, wire-guided [anti-tank missile]
TPS	transportable, ground use / radar / detection (in radar and electronics equipment designations)
TR	tactical reconnaissance (in an aircraft designation)
TREES	Transient Radiation Effects on Electronics Systems
TRIGA	Training, Research, Isotopes General Atomics
TRW	Thompson Ramo Wooldridge
TVA	Tennessee Valley Authority
TWA	Transcontinental and Western Air, Inc.; TransWorld Airlines
TWT	traveling wave tube
U	uranium; utility (in an aircraft designation)
UHF	ultra-high frequency
USACERL	United States Army Construction Engineering Research Laboratories
USAFE	United States Air Forces in Europe
USAFSAM	United States Air Force School of Aerospace Medicine
USAFSS	United States Air Force Security Services
UTTR	Utah Test and Training Range
V	Vergeltung (vengeance)
VB	vertical bomb
VC	staff administrative cargo (in an aircraft designation)
VE	Victory in Europe
VHB	very heavy bomber
VHF	very-high frequency
VKF	Von Karman Gas Dynamics Facility
VLF	very low frequency
Volir	volumetric interception radar
Volscan	volumetric scanning radar
VOR	VHF Omnidirectional Range
VPD	Vertically Polarized Dipole
VVHB	very very heavy bomber
WACS	White Alice Communications System

WADC	Wright Air Development Center
WAF	Women in Air Force
WAI	Weidlinger Associates Incorporated
WB	weather reconnaissance bomber (in an aircraft designation)
WDD	Western Development Division
WO	work order
WPA	Works Progress Administration
WRADCA	Warner Robins Air Depot Control Area
WRALC	Warner Robins Air Logistics Center
WRAMA	Warner Robins Air Materiel Area
WRM	War Readiness Materiel
WRS	Weather Reconnaissance Squadron
WS	weapons system
WS^3	Weapons Storage and Security System
WSTP	Waste Storage and Treatment Plant
X	experiment (experimental)
XB	experimental bomber (in an aircraft designation)
XC	experimental cargo (in an aircraft designation)
XD	experimental development (digital?)
XF	experimental fighter (in an aircraft designation)
XP	experimental pursuit (in an aircraft designation)
XV	experimental vehicle
XW	experimental weapon
Y	prototype
YB	prototype bomber (in an aircraft designation)
YP	prototype pursuit (in an aircraft designation)
Z	Jerrold R. Zacharias (Z Division, Sandia)
ZD	Zeiss Dywidag
ZEL	zero length launcher

Chapter 1: Arnold Air Force Base

Historic Missions of the Cold War

The Cold War missions of Air Research and Development Command (ARDC) / Air Force Systems Command (AFSC) at Arnold Air Force Base were numerous, and included development projects for many of the weapons systems, aircraft, and spacecraft under development as of 1953. The earliest reference to an aeronautical test facility for the evolving research and development (R&D) needs of aircraft and armament dated to August 1944, when the Engineering Division at Wright Field expressed strong interest in possessing a high-altitude wind tunnel large enough to test full-sized propellers.[1] To some degree, the desire for improved test equipment derived from the knowledge that the Germans had such wind tunnels in place, and that they had research facilities organized to support them (such as the Hermann Göring and Kaiser Wilhelm Institutes). Before the close of 1945, Dr. Theodore von Karman, in *Toward New Horizons*; the Engineering Division at Wright Field; and, the British Royal Air Force (RAF) each called for the installation that Arnold would become during the early 1950s (see Volume I, Part II). Ideas toward a test center first named the Air Engineering Development Center, and later Arnold Engineering Development Center (both using the acronym AEDC), continued into the late 1940s. Site studies evaluated possible locations for the center in more than one part of the country. Public Law 415, 81st Congress, authorized the AEDC in October 1949, with a redesignation from the Air Engineering Development Center to the Arnold Engineering Development Center in February 1950. The Air Force had earmarked specific pieces of World War II German equipment for reerection at Arnold by the time of initial construction in 1951. Headquarters ARDC added to these to create a state-of-the-art industrial research test site tapped by a wide variety of users in a collaborative enterprise between government and aircraft / weapons systems manufacturers. The base is an atypical installation in every way. Non-ARDC / AFSC missions at Arnold are also unlike those at other Air Force installations, with no true tenant missions on base (such as Strategic Air Command [SAC] or Air Defense Command [ADC] alert). Customers using Arnold's testing apparatus range across other Air Force organizations, the Department of Defense, the National Aeronautics and Space Administration (NASA), American private industry, allied foreign governments and industry, and educational institutions.[2] The larger Air Force installation supporting the AEDC was Arnold Air Force Station throughout most of the Cold War, although the designation as an Air Force Station did not become formal until May 1979. In late 1987, Arnold Air Force Station became Arnold Air Force Base. In the middle 1990s, Arnold Air Force Base briefly returned to the name Arnold Air Force Station, but almost immediately was redesignated as an Air Force Base.

Primary Missions

Examples of major Cold War missions at Arnold Air Force Base included testing:

- aircraft and / or aircraft components;
- the Super-Tarpon nuclear-powered bomber;
- Falcon, Bomarc (Boeing Michigan Aeronautical Research Center), Navaho, Sergeant, Sparrow, Snark, Quail, Automet / Lance, Skybolt, Bullpup, Dart, and Trailblazer (Air Force, Army, and Navy) guided missiles;
- the Little John artillery rocket (Army);
- Thor (Air Force) and Jupiter (Army) intermediate range ballistic missiles (IRBMs);
- Redstone, Atlas, Titan, Minuteman, Pershing, Peacekeeper (Air Force and Army) intercontinental ballistic missiles (ICBMs);
- Polaris, Poseidon, and Trident (Navy) sea-launched ballistic missiles (SLBMs);
- Nike-Zeus and Sprint antimissile missiles (Army);
- target missiles;

- the Advisory Group for the Aeronautical Research and Development (AGARD) North Atlantic Treaty Organization (NATO) missile, the folding fin air-to-air rocket (FFAR), the short-range attack missile (SRAM), the subsonic cruise armed decoy (SCAD), the air-launched, air-recoverable rocket (ALARR), the air-launched, ground-attack missile (AGM), the advanced strategic air-launched missile (ASALM), the air launched cruise missile (ALCM), the advanced medium-range air-to-air missile (AMRAAM), and the Tomahawk cruise missile;
- sounding rockets;
- balloons and ballutes;
- items for the Dyna-Soar program;
- satellites;
- a Manned Orbiting Laboratory;
- items for Sandia Laboratories and for the Advanced Research Projects Agency (ARPA);
- components of the System for Nuclear Auxiliary Power (SNAP);
- shell ballistics;
- stores separation;
- bombs and cluster munitions; and,
- warheads (nose cones).

Tenant Organization Missions

Although no true tenant missions existed at Arnold in a manner paralleling such missions at other Air Force Materiel Command installations, testing for NASA is mentioned here. NASA's missions were often closely linked to ARDC / AFSC Cold War missions, with NASA a tenant at key ARDC / AFSC bases. NASA testing at Arnold included:

- the Ranger, Centaur, Surveyor, Saturn V, and Apollo lunar probe, landing, orbital, and excursion crafts;
- Mercury, Saturn, Apollo, Gemini, and Orbiter spacecraft;
- Thor, Atlas, Jupiter, Saturn, Agena, Scout, Thor-Delta, Titan-Agena, and Agena / Gemini multistage launch vehicles;
- items for the Anchored Interplanetary Monitoring Program;
- the Space Shuttle; and,
- studies toward the effects of space debris.

Chronology

With the ending of World War II in Europe, scientific and engineering representatives for the Army Air Forces realized that the American military required a major new aeronautical research and test installation that incorporated state-of-the-art wind tunnels and other facilities. By June 1945, the Engineering Division at Wright Field had focused ideas toward such an installation and defined it as an independently located "development center." R&D projects anticipated for the center required massive amounts of electricity, while the types of facilities planned also necessitated large tracts of land. These two factors suggested a careful comparative study of potential sites,[3] eliminating the Dayton area as the likely location for such a center. In October, a committee of personnel at Wright Field further evaluated ideas for an Air Engineering Development Center. As of November 1945, the RAF suggested to Headquarters Air Technical Service Command that Bedford Field near Boston would be the appropriate site for setting up both confiscated equipment from the Hermann Göring and Wilhelm Kaiser Institutes of Brunswick and Göttingen, respectively, and for reestablishing German scientists and engineers held by the Americans and the British (Volume I, Part II). The Bedford Field

site, which would become Hanscom Air Force Base, was close to the Massachusetts Institute of Technology (MIT) and its critical World War II Radiation Laboratory (Volume II, Chapter 5).

By mid-December 1945, the Engineering Division of Air Technical Service Command at Wright Field submitted its report *Proposed Air Engineering Development Center* to the Air Staff. The envisioned Air Engineering Development Center included both laboratory and flight test areas, with peripheral sites for housing and hazardous materials, all spread over a 100-square-mile area (Plate 1). (See also, Volume I, Plate 60.) Specifics called for five wind tunnels, static rocket test stands, ramjet test facilities, hot and cold chambers, a materials test and processing area, an electronics and wave phenomena facility, a physiological compound (which would become the Aerospace Medical Center at Brooks Air Force Base in 1959-1960), fuel and propellants laboratories, an instruments development center (including high-speed computers), and flight engineering facilities with runways, aprons, multiple static test stands and a firing range (roles later filled through the Flight Test Center at Edwards Air Force Base and the Armament Test Center at Eglin Air Force Base).[4] Dr. Theodore von Karman also called for such a center in the 12-volume guide to future Air Force R&D, *Toward New Horizons*, directly following the efforts at Wright Field (see Volume I, Parts II and III). The hypothetical AEDC was much more encompassing than the center as built.

Programmatic plans for the developmental research and test installation that became the Arnold Engineering Development Center also overlapped similar plans for a national aeronautical center required by the National Advisory Committee of Aeronautics (NACA)—the predecessor of NASA. During this same period, NACA studied ideas for a National Supersonic Research Center (NSRC). By spring 1946, higher-level Federal considerations tied the two proposed centers of the AEDC and the NSRC together, with a civil engineering firm hired in about June to conduct site surveys. That firm, Sverdrup & Parcel of St. Louis, had been a key participant in military engineering efforts of World War II. Major General Leif J. Sverdrup was General Douglas MacArthur's commander of engineering forces in the southwestern Pacific during the war, and was himself a distinguished and highly decorated soldier. While preparations for a national aeronautical center commenced, the Federal government divided up the captured German wind tunnels among NACA, the Army Air Forces, and the Navy. Discussion at Wright Field for an AEDC continued with multiple alternate plans that featured if-this, then-that contingencies for Wright Field, the Watson Laboratories, the Cambridge Field Station (future Hanscom Air Force Base), Rome Field (future Griffiss Air Force Base and site of the Rome Air Development Center), and Eglin Field. At Wright Field, for example, the command planned an all-wood radar test building for immediate design rather than wait for possible inclusion of such a facility at the AEDC.[5] Sverdrup & Parcel, after their survey for what was loosely discussed as transonic and supersonic wind tunnel facilities, submitted a formal report in mid-November 1946 that recommended locations for both the Army Air Force's AEDC and NACA's NSRC—the two installations tied together at upper Federal levels as the Unitary Plan on Wind Tunnels.[6]

Sverdrup & Parcel's November report contained not only suggested sites, but also drawings of preliminary facilities and cost estimates for an AEDC and an NSRC. The first ideas presented were broad. The scheme for an AEDC focused on wind tunnels for the industrial site, although did include plans for a supporting community. The report projected total costs at over $1.5 billion for the Army Air Forces installation. Before the close of 1946, NACA chose to withdraw from the joint planning effort through Sverdrup & Parcel, with the engineering firm moving forward for the Army Air Forces alone. NACA removed its allotted wind tunnels from the Unitary Plan. Another document discussing the wind tunnel needs of the Army Air Forces, Navy, the Civil Aeronautics Association (CAA), and NACA went before the Joint Research and Development Board (JRDB) proposing 10-year costs of over $1 trillion. The Army Air Forces diverged further from NACA by early 1947. In February, Major General Curtis LeMay, then Deputy Chief of Air Staff for Research and

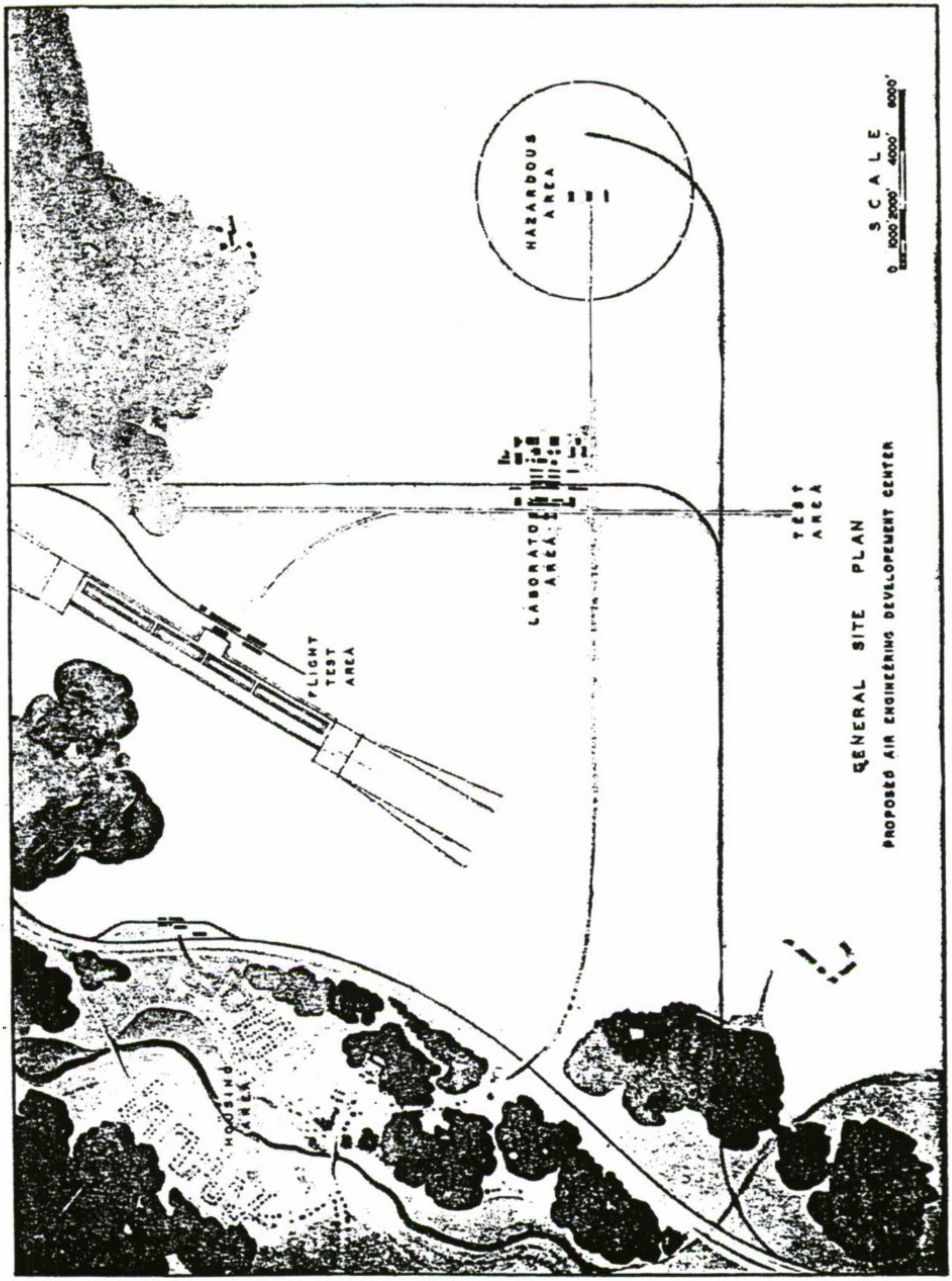

Plate 1: Air Engineering Development Center. General Site Plan, 10 December 1945. In *Proposed Air Engineering Development Center.* Courtesy of the History Office, Arnold Engineering Development Center.

Development, proposed that the Army Air Forces required more infrastructure than wind tunnels alone, with a new Army Air Forces' estimated cost for an AEDC at nearly $540 billion.[7]

LeMay's conception for an AEDC was expansive.

> Facilities planned for the center would require power and water supplies far beyond the capacity of any existing Air Force establishment. As initial installations, the Research and Development Board approved for immediate construction a high-altitude-engine-wind tunnel. Research and experimentation were to be done in fluid dynamics, thermodynamics, electronics, and wave phenomena. Exhaustive tests were to be made of propellants and instruments. In the field of thermodynamics, the center was designed to provide research in jet engines and in the use of heat for energy, possibly through nuclear fission or atomic energy; and the electronic and wave phenomena study was to demand work in radio control, radar, Loran [long-range radio navigation], television, homing devices, guided missiles, and the cosmic and other rays.[8]

As of early 1947, the Air Force had two plans under consideration: the original Unitary Plan for wind tunnels and an increasingly comprehensive plan for an AEDC. The ambitious scope of Army Air Forces efforts, as well as perceived competition between the military agency and the civilian NACA, led to stalls as the year unfolded. By very late in the year, the Committee on Aeronautics of the Research and Development Board approved an AEDC for the Air Force (transitioned from the Army Air Forces as of July 1947), but with no specific components. At this juncture, projected costs for an AEDC were about $380 billion. Study toward both an AEDC and the Unitary Plan continued through the Research and Development Board, with a recommendation for further site and facility analyses for an AEDC. The Unitary Plan included both the wind tunnels for NACA, as well as those for the Air Force and other research entities. Sverdrup & Parcel executed more site surveys across the country during 1948 into late 1949[9] (see Volume I, Part II). As of April 1948, recommendations for the AEDC leaned toward Camp Forrest, Tennessee. The Research and Development Board also suggested that first facilities use captured Bavarian Motor Works (BMW) engine test equipment and supersonic wind tunnels to start operations.[10] The Air Force then drafted the framework for a Senate bill that authorized the establishment and construction of an AEDC. During the first half of 1948, the agency gathered the formal concurrence of both the Army and the Navy. Draft legislation for the Unitary Plan went ahead simultaneously. By autumn, the Bureau of the Budget requested that the two bills be combined, with distinct subsections focused on the wind tunnels (Title I) and on an AEDC (Title II). As of February 1949, the revised draft legislation sought authorization for "a unitary plan for construction of transonic and supersonic wind tunnel facilities, and the establishment of an Air Engineering Development Center." Congressional hearings began in April for what would be Public Law 415.[11]

Presentations before Congress on the Unitary Plan and an AEDC did not finish up during the spring 1949 session, but instead resumed late that summer. Speakers for the Air Force, NACA, the Navy, and the university community testified in favor of the facilities. In May, at the request of the Air Force, the Tennessee Valley Authority (TVA) prepared a brief report on sites appropriate for an AEDC. TVA locales offered "power supply, water supply, suitable land areas, and satisfactory living conditions for operating personnel." Under consideration were the Huntsville Arsenal; an area west of Florence, Alabama, near the Tennessee line; Camp Forrest near Tullahoma, Tennessee; and,

Smyrna Field, southeast of Nashville. Air Materiel Command, under whom an AEDC fell, projected that the research-test installation would

> need power in the following amounts within five years: 16,000 kilowatts during hours of system peak loads, with a load factor of 50 percent; and a maximum demand of 237,000 kilowatts during the power system's off-peak hours, the additional 221,000 kilowatts to be at a load factor of 16.5 percent.[12]

The Senate and House of Representatives passed bill S-1267 in August 1949 (with amendments, in October 1949).[13] The 81st Congress approved the revised bill as Public Law 415 on 27 October 1949 and authorized $100 million for the AEDC. Title I of the act was alternately known as the Unitary Wind Tunnel Plan Act of 1949, while Title II was alternately known as the Air Engineering Development Center Act of 1949. Under Title II of Public Law 415

> [t]he Secretary of the Air Force is authorized to establish an Air Engineering Development Center, and to construct, install, and equip (1) temporary and permanent public works, including housing accommodations and community facilities for military and civilian personnel, buildings, facilities, appurtenances, and utilities; and (2) wind tunnels in implementation of the unitary plan referred to in title I of this Act; and to maintain and operate the public works and wind tunnels authorized by title II of this Act.[14]

Congress made $30 million available for 1950 through Public Law 430, with an obligation of funding beyond 1950 held for a later date. In early November 1949, the Secretary of the Air Force announced that Air Materiel Command would locate the AEDC at Camp Forrest, Tennessee. More Congressional testimony followed to accelerate the funding process. In June 1950, the 81st Congress approved Public Law 583 to appropriate $55 million for immediate construction of the center. In September 1950, the 81st Congress obligated an additional $15 million through Public Law 759. As the funding accelerated, the Research and Development Board also asked the Air Force to enlarge its vision for the AEDC. In late September 1950, the 81st Congress amended the total for the center from $100 million to $157.5 million (Public Law 799) and approved the appropriation of $57.5 million through Public Law 843 at the same time.[15] The more than six-year planning process toward an AEDC within Air Materiel Command climaxed in autumn 1950.

From 1945 through mid-August 1949, planning toward the AEDC had focused within Air Materiel Command at Wright Field (Wright-Patterson) and the Directorate of Research and Development at Headquarters Air Force in Washington, D.C. When S-1267 went before Congress in August 1949, Major General Franklin O. Carroll became project manager for the AEDC through the Deputy Chief of Staff, Materiel, at Headquarters Air Force. In mid-October, General Carroll transferred from his position as Director, Research and Development, at Air Materiel Command to Washington, D.C., as Assistant to the Deputy Chief of Staff, Materiel. The AEDC became established temporarily as a command under the Chief of Staff, United States Air Force, with the designation of an Air Engineering Development Division (AEDD) on 30 December 1949. The AEDD was to function as a tenant at Wright-Patterson in Ohio until initial construction at Camp Forrest was sufficiently completed. Personnel for the AEDD transferred directly from the Engineering Division at Air Materiel Command during early 1950, with Air Materiel Command also providing additional support for the interim effort. The AEDD operated as a separate agency directly under the Chief of Staff, United States Air Force, with the procedural functions and duties of a major command.[16] In November 1950, the AEDD moved from Wright-Patterson to the permanent location of the AEDC in Tennessee. As of May 1951, the Air Force assigned the AEDD to ARDC.[17]

While Congress incrementally approved augmented funding for the AEDC during 1950, the Air Force Base Development Board appointed the Ad Hoc Committee on Master Planning for AEDC to make the initial decisions required for the center. The Air Force took control of the design and engineering process for the individual buildings at the AEDC, as was the case for many Air Force projects during the early 1950s (see Volume I, Part III)—and for nearly all of those of high importance within Air Materiel Command / ARDC. The agency allotted the United States Army Corps of Engineers the tasks required for the overall support infrastructure. The Corps' role included responsibility for the streets, fencing, lighting, railroads, sewer system, cooling water distribution, dam and reservoir, communications, steam generating plant and its distribution works, shipping and receiving warehouse, administration and engineering building, cafeteria, fire and police building, industrial dispensary, reception center and gate house, foundry, installations maintenance shop, and automotive repair shop. The Corps contracted with individual architectural-engineering firms for these projects. The Air Force, through its engineering contractor, was responsible for the main technical facilities, electrical distribution system, test fuel storage and distribution system, instrument shop, and model shop.[18] The first Air Force personnel arrived at the Tullahoma site at the end of February 1950. On the 10th of that month, the generic Air Engineering Development Center became the Arnold Engineering Development Center in honor of General Henry "Hap" H. Arnold. General Arnold had a long and distinguished career with the Army and Air Force, and had filled a fundamentally important role in early decisions toward post-World War II military air-power R&D (Volume I, Part III). General Arnold had died of a heart ailment in California the preceding January. At this same time, the Air Force negotiated a revised contract with Sverdrup & Parcel for the master plan and design of the technical facilities, in line with decisions of the Research and Development Board for the installation.[19]

Sverdrup & Parcel's first contract of 28 June 1946 for the AEDC and NSRC study had initiated design of technical facilities. The firm's report of November 1946 featured line drawings for 15 AEDC buildings and structures proposed by the Air Force. Ultimately, the Research and Development Board approved only three of these earliest facilities: the Engine Test Facility (ETF), Gas Dynamics Facility (GDF), and Propulsion Wind Tunnel (PWT) (in 2000, subsumed as multiple individual units within the 500- and 800-series, the 600-series, and the 700-series buildings at the center, respectively). As of September 1947, the Air Force stopped further work by Sverdrup & Parcel for a 30- by 30-inch transonic wind tunnel, two six- by six-foot hypersonic wind tunnels, two eight- by eight-foot supersonic aerodynamic wind tunnels, and a 40- by 40-inch "fire test" (transonic propulsion) tunnel.[20] Change orders continued through 1948, with design steadily focused on particular facilities. Sverdrup & Parcel carried their efforts for a propulsion components laboratory only to a preliminary level, while the Air Force directed the firm to undertake detailed design and engineering of a gas dynamics facility. In May 1948, Sverdrup & Parcel began final design of the ETF. The Engineering Division, Air Materiel Command, at Wright-Patterson simultaneously undertook a study to analyze the preferred combination of confiscated German and procured American equipment. The BMW engine test plant equipment, used during World War II in Germany to test turbojet and gas turbine power plants, would be the ETF's core. The AEDC would also incorporate two German wind tunnel complexes into its design. The GDF would test supersonic and hypersonic aircraft and missile models "at conditions approaching those of flight."[21] The Air Force authorized Sverdrup & Parcel to hire "outside consultants" for specialized needs in the design process as of change order 12 in November 1949.[22]

During spring 1950, high-level discussions began addressing the management and operation of the future installation. The Secretary of the Air Force requested that the Scientific Advisory Board (SAB) appoint a committee to review the challenges facing the AEDC in its missions across multiple military and civilian agencies, private industry, and universities. The SAB established the Special Committee on AEDC Operation led by Professor John R. Markham of MIT. The 10 members of the

committee included four men already assigned to the AEDC, along with two professors from MIT and four representatives from private industry (from McDonnell Aircraft, North American Aviation, Boeing Aircraft, and the Hughes Tool Company). In its study, generally referenced as the Markham Report of April 1950, the committee noted that its members had reviewed the operation of the Atomic Energy Commission (AEC) laboratories at Los Alamos and Sandia, in New Mexico, as well as that of Brookhaven on Long Island. These three important American laboratories served as primary models. The committee observed a number of key points with respect to an effective operation of the AEDC. In order to allow industry to undertake developmental testing as a customer of the AEDC—for not only military contracts, but also for purely company work—operation would need to insure safeguarding of proprietary rights. The AEDC would link private or university contractors to higher agency review when the center's facilities supported evaluation testing of items already developed for the Air Force or for other military service agencies. In this role, the AEDC would become a type of service organization. The Air Force also intended that personnel at the AEDC be able to conduct in-house Air Force R&D on site. The committee interpreted the three different roles of developmental testing, evaluation testing, and in-house Air Force R&D as weighted in a 70 / 20 / 10 percentage to the overall mission of the AEDC. While the AEC laboratories were university-managed and operated, the committee felt that this choice was inappropriate for the industrial setting of the AEDC, and for its relatively low percentage of purely scientific endeavor.[23]

The Markham Report recommended a newly formed at-cost corporation comprised of "outstanding representatives from the aircraft industry and universities, and other public spirited citizens." Several of the committee members further recommended that the new corporation be tiered directly to a for-profit parent corporation with an established presence in aeronautical industry. Dr. von Karman submitted the SAB committee recommendations to the Secretary of the Air Force on 12 April 1950.[24] Within a week of Dr. von Karman's presentation, the Deputy Chief of Staff / Materiel at Headquarters Air Force informed Air Materiel Command at Wright-Patterson that the AEDC would be managed and operated on a cost-plus-fixed-fee contract by a corporation established through Sverdrup & Parcel. In mid-April 1950, Sverdrup & Parcel established the Arnold Research Organization (ARO, Inc.).[25] ARO submitted its preliminary plan for managing the AEDC in late October 1950. The firm divided its efforts into the three stages of planning, partial activation, and full operations. ARO anticipated that personnel would rise from a small initial nucleus in January 1951 to about 1060 people five years later. ARO managed and operated the AEDC from 1951 to 1981,[26] when the Air Force began to split up the contract. In 1977, the operating contract for AEDC had become competitive, with ARO and Burns & Roe initially vying for the project. ARO subsequently changed names to Sverdrup Technology. The first three companies to operate the AEDC as of the new management approach were Pan Am, Calspan, and Sverdrup. Schneider replaced PanAm in the next bidding cycle for the contract. From this point forward, operation and management of the AEDC became more complex. As of 2000, two prime contractors run the AEDC, one of which remains Sverdrup (Jacobs)—derived from the original ARO.[27]

Construction for the AEDC was underway in 1950. The Corps of Engineers handled the design of the cooling water dam as a first priority, with land acquisition and administration set up immediately. Components of the ETF derived from the BMW jet engine test plant in Munich. The Army Air Forces had stored these components in warehouses in Alameda, California; Mobile, Alabama; and, Memphis, Tennessee, after their removal from Germany. Built during 1941-1944, the BMW plant had been operational at the end of the war and was a state-of-the-art facility. After winning the war in Europe, the Army Air Forces and the RAF had run engine tests in the plant, dismantling it in 1946 for partial shipment to the United States.[28] As of mid-August 1950, Air Materiel Command had shipped 52 train carloads and two barge loads of BMW engine test equipment to the AEDC site from Alameda (the primary storage location), with an additional six carloads from Memphis and 450 tons from Mobile. Uncrating and reconditioning began in late September in a shop at William Northern

Field, the airport in Tullahoma. Workmen stored many German equipment parts out in the open on the concrete apron, with significant rust deterioration by the following summer.[29] Contractors started excavation for the ETF buildings in mid-August 1950, just as the last of the funding augmentation was beginning to move through the 81st Congress. The Army Corps of Engineers continued progress toward the basic site infrastructure through the year, with its dam and reservoir about six percent completed by the close of December.[30]

During 1951-1952, priorities for individual technical facilities were the ETF, GDF, and the PWT. While the BMW engine test plant equipment was central to the ETF, Sverdrup & Parcel nonetheless faced many design and engineering challenges in completing the facility. Advances in jet propulsion plants required new equipment, test chambers, a climate control plant, and additional instrumentation. The ETF featured six basic components: its refrigeration drying equipment, four air supply compressors, three test chambers, a test bed, exhaust gas coolers, and six exhausters. For testing, personnel moved engines along railroad tracks to one of the 12-foot diameter test chambers (each with possible extension to various lengths). The chambers connected to control rooms with test instrumentation.[31] Engineers designed the ETF to simulate altitudes up to 80,000 feet. (The original BMW engine test plant in Munich accommodated testing for simulated altitudes up to 54,000 feet.)[32] Planned funding for the ETF was approximately $18.4 million.[33] Sverdrup & Parcel also augmented the supersonic and hypersonic wind tunnel group for the GDF, based on the design and construction of a German facility, the Gas Dynamics Institute at Sonthofen (formerly attached to the Deutsche Versuchsanstalt für Luftfahrt [DVL] in Berlin). The Gas Dynamics Institute at Sonthofen was another state-of-the-art facility just under construction at the end of the war. German engineering drawings, as well as some equipment, were made available to the firm.[34] Sverdrup & Parcel added a Tunnel E, splitting it into two test sections for low and high Mach numbers (Plate 2). Tunnel A was a 40- by 40-inch section for Mach numbers of 1.2 to 5; Tunnel B, a 40- by 40-inch section for Mach numbers of 5 to 10. The AEDD deferred construction for Tunnels D and F—with Tunnel F planned for testing at Mach numbers of 10 to 20 for very short periods. Tunnels E-1 and E-2 were each 12- by 12-inch test sections, with Tunnel E-1 an early priority as the prototype for Tunnel A. Equipment at the Jet Propulsion Laboratory in Pasadena, California, provided the model for the Tunnel E-1. Anticipated funding for the GDF was just under $22 million.[35] In November 1951, the Air Force awarded a contract to the Allis-Chalmers Manufacturing Company for a ramjet addition to the ETF. The addition was a separate test facility first configured as three cells and revised to two in mid-1952.[36]

The PWT was perhaps the premier facility of the ETF, GDF, and PWT trio. Engineers planned the wind tunnel as a continuous-flow, closed-circuit tunnel with two test sections. Sverdrup & Parcel altered the performance characteristics of the equipment to accommodate both transonic and supersonic tests (up to Mach 3.5). The firm also enlarged the supersonic part of the tunnel to create a test section 16 feet square (Plate 3). The PWT was "designed for development testing of full-scale, operating, ram-jet and turbo-jet power plants, as installed in missiles and aircraft, as well as full-scale components of aircraft and missiles." The transonic part of the tunnel as initially designed was to be octagonal, "18 feet across the flats" (for testing up to Mach 1.5).[37] Planned funding for the PWT was $51 million, but anticipated real costs were nearly $72 million.[38] Operating requirements for the PWT were daunting.

> The maximum air flow through the wind tunnel will be approximately equivalent to the air requirement of 350 F-80 fighters at full power at sea level. The coolers for temperature control will use about 100,000 gallons per minute of cooling water, a rate equal to that required by a city the size of Washington. Approximately

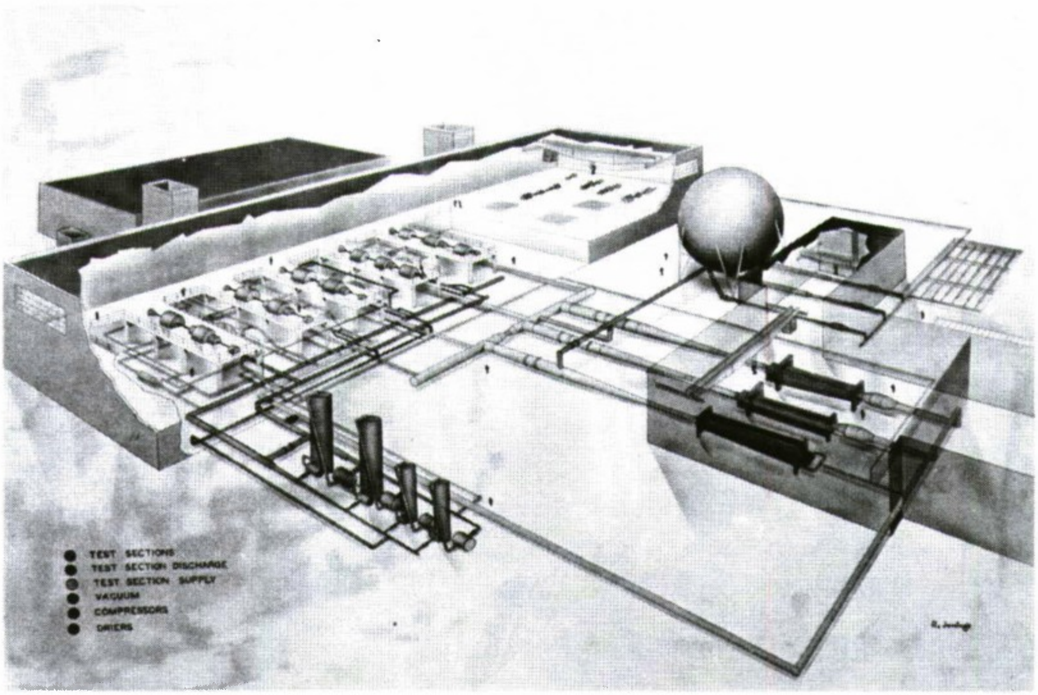

Plate 2: **Sverdrup & Parcel. Schematic Drawing for the Gas Dynamic Facility, Arnold Engineering Development Center, 1951. In *History of the Arnold Engineering Development Center 1 January – 30 June 1951*, volume 3.**

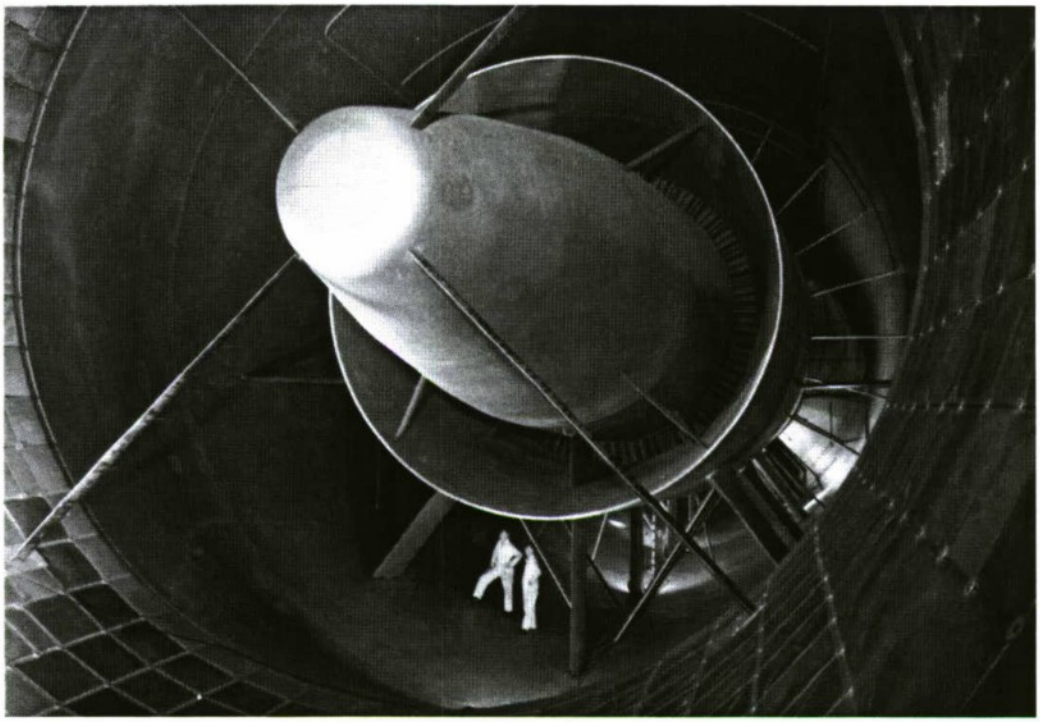

Plate 3: **Sverdrup & Parcel. Turbine for the Propulsion Wind Tunnel, Arnold Engineering Development Center, 1960. Courtesy of Public Affairs, Arnold Engineering Development Center.**

> 200,000 hp. [horsepower] will be required to operate the tunnel, a power demand equivalent to a city of over 100,000 population. ...designed primarily as a propulsion tunnel, it will also provide developmental testing of full-scale or very large-scale models of aircraft and missiles or components without motors.[39]

The AEDD at Wright-Patterson continued to manage the engineering from the Air Force perspective, with technical and administrative control over Sverdrup & Parcel and ARO, Inc. The Division worked closely with the Corps of Engineers. AEDD planned for an 8,000-foot airfield, 200 feet wide with 1,000-foot overruns.[40] The dam on the Elk River provided the large amount of electrical power and water required by the industrial facilities at the AEDC. This structure was of earthen-fill and concrete type, approximately 90 feet high and 3,000 feet across. The reservoir created by the dam covered 5,000 acres, with a storage capacity of about 100,000 acre-feet of water. Impoundment of water was in progress before the end of 1951, with completion of the dam and reservoir during 1952. Three miles upstream from the dam, a primary pumping plant sat on the north side of the reservoir. The plant raised the water stored in the main reservoir about 140 feet through a five-foot intake pipeline to a secondary reservoir immediate to the AEDC. A pumping plant at the secondary reservoir distributed water to AEDC facilities. The secondary reservoir stored 14,000,000 gallons of water.[41] AEDC water usage in 2000 was the equivalent of draining the secondary reservoir four times. After each use, center personnel cleaned and rechanneled the water back to its containment structure.[42] President Truman dedicated the AEDC in Tullahoma on 25 June 1951.

The new installation also benefited directly from German scientists, engineers, and technicians through Project Paperclip, in addition to the incorporation of wind tunnel and engine test equipment into the ETF and the GDF (see Volume I, Part III). As of early 1947, Air Materiel Command at Wright Field had assigned nine Paperclippers to the preliminary planning efforts toward the Air Engineering Development Center: Drs. Eckert, Hartung, Hermann, and Arnold, and Mr. Dellmeier, Hoh, Ramm, Volk, and Walk. Of these men, Dr. Arnold and Mr. Ramm would both move to the operational AEDC in Tennessee. Air Materiel Command also loaned Karl Volk, a hydroelectric expert, to Sverdrup & Parcel as of February 1947, to work on AEDC engineering plans in the firm's St. Louis office. Led by Dr. Bernard Goethert, four Paperclippers arrived in Tullahoma by early 1952. Dr. Goethert had arrived in the United States in November 1945. He had served as the section chief for wind tunnel testing at Wright Field. In mid-November 1952, ARDC appointed him the chief of the PWT as an employee of ARO, Inc.[43] Heinrich Matt, Heinrich Ramm, and Gottfried Arnold also transferred from Ohio to the AEDC with Dr. Goethert. Dr. Arnold, who had been with Wernher von Braun's group at Peenemünde during World War II and also in the United States as of November 1945, was a research coordinator for the Engineering Division at Wright-Patterson. Other Paperclippers who transferred to AEDC during the middle and later 1950s included Dr. Hans K. Doetsch, Karl Thormaehlen, Alex Kolb, Hans Rister, Mathias Hickertz, Otto Bock, Hermann Schneider, Alfred Windmueller, and Emil Salmon (see Volume I, Plate 50). Of the group, Mr. Kolb, Rister, Hickertz, and Bock arrived from Wright-Patterson. Two men, Bock and Rister, had been among the vanguard group of six Paperclippers who had gone to Headquarters Air Materiel Command at Wright Field in September 1945. The eminent German scientist Dr. Gerhard Braun, who had worked at Wright-Patterson and Holloman Air Force Bases during the late 1940s and 1950s, joined the staff of the Space Institute in Tullahoma in the late 1960s. Dr. Braun was also among the first six Wright Field Paperclippers of September 1945.

During spring 1952, the Engineering Division at Wright-Patterson also conducted a study of foreign wind tunnels using the expertise of its Paperclippers. In March, Dr. Arnold wrote an analytical paper on the supersonic 16- by 16-inch wind tunnel operated during the war for the German Air Research Institute in Munich. Dr. Arnold noted in his technical report that the Army Air Forces had dismantled

the tunnel in 1945 and had shipped it to the United States. ARDC had possession of the tunnel, with its parts stored at Wright-Patterson. Dr. Arnold argued that the tunnel should be erected at the AEDC, with a probable cost of between $236,000 to $338,000 for reconstruction and an associated building. Personnel at Wright-Patterson were refurbishing the wind tunnel's components, simultaneously designing and constructing its missing parts (through Project Blowhard).[44] Guenther Dellmeier, one of the Paperclippers who had worked on early AEDC planning, also authored a technical report on another confiscated wind tunnel. His report of April 1952 on the Yokosuka wind tunnel illustrates that analysis was not limited to German equipment, but also included that of Japan. The Air Force had dismantled the transonic Yokosuka wind tunnel in Japan in 1947, shipping it to the United States in December 1949. Tunnel components had remained crated for two-and-one-half years or more, again with storage in the open. Components included its 40-inch diameter, circular-shaped test section. The Air Force shipped the Yokosuka tunnel parts to the AEDC by 1952. Mr. Dellmeier's detailed analysis suggested that the tunnel could be refurbished, with costs of $170,000 to make the equipment operational. (Mr. Dellmeier continued to work at Wright-Patterson rather than transfer to the AEDC.)[45] By the end of June 1952, installation of the German equipment in the ETF was 48 percent complete.[46]

During 1952-1953, the AEDC faced decisions regarding the mechanics of running military, contractor, and university test programs while construction for the center was in progress and personnel began to arrive. The decisions included prioritizing projects, allocating time, determining the level of support to be provided by AEDC personnel, and establishing a schedule of charges. The interface with NACA and Navy wind tunnel complexes was of foremost consideration, in part due to ties established through the Unitary Plan.[47] As of mid-1952, Department of Defense policy called for the Air Force, Army, and Navy to reimburse each other when using facilities. At that date, specialized defense test facilities handled in this manner included the Army's wind tunnels at the Aberdeen Proving Ground in Maryland and the wind tunnels at the Jet Propulsion Laboratory in California; the Navy's Supersonic Laboratory at MIT, its Ordnance Laboratory in Maryland, and its Ordnance Aerophysics Laboratory in Texas; and, ARDC's propeller whirl rig, wind tunnels, and power plant laboratory at Wright-Patterson in Ohio. NACA was in conflict with this policy. A civilian agency, NACA had never charged the defense agencies for tests run at its facilities. The commander of the AEDC in July 1952, Colonel C.K. Moore, recommended that the Air Force assess the Army and Navy for their tests, and that the Air Force advise NACA to begin charging for services that had been free. NACA erected a $27-million supersonic wind tunnel complex at Moffett Field south of San Francisco, the Ames Aeronautical Laboratory, while ARDC went forward with construction for its AEDC in Tennessee.[48] Both the Arnold and Ames wind tunnel facilities had been conceived through the Unitary Plan on Wind Tunnels of 1946. Some analysts feared that operating the AEDC would be very expensive, and that the facility required treatment as a business. The price estimates in July 1952 factored in the costs of power, fuel, equipment, supplies, and ancillary purchases, but excluded overhead, salaries, and depreciation. Colonel Moore proposed fees on a per-test-hour basis: $1,650 for PWT aerodynamic tests; $2,430 for PWT propulsion system tests; $1,230 for the ETF; $1,750 for the ramjet addition to the ETF; $400 for the low Mach test section of the GDF; and, $600 for the high Mach test section of the GDF.[49]

As of late April 1953, with first tests at the AEDC still ahead, Headquarters ARDC in Baltimore issued a formal statement entitled "Research and Development: Operation of Facilities of the Arnold Engineering Development Center." Contrary to the preliminary recommendations of Colonel Moore, ARDC decided that "[a]ll costs involved in the operation of the AEDC facilities will be computed by the AEDC and included in the ARDC budget and the Navy, Army, and other using agencies will assist in the preparation, presentation, defense, and justification of the AEDC budget." Thus, the Air Force decided not to charge its sister military agencies and instead followed the policy of NACA for use of its test facilities at the AEDC. ARDC further decided that the AEDC would forego charges to

private industry customers working under contract "or the sponsorship of the military services of the Department of Defense." In a related policy, the AEDC would impose fees for only "the total direct cost" of private industry or university projects of a proprietary nature. The Air Force gave first priority for testing to agencies within the Department of Defense, second priority to research, development, and evaluation projects sponsored by the military services, and lowest priority to proprietary work whose intent was primarily "to enhance the firms [*sic*] competitive position in the commercial market." ARDC's policy for the AEDC, ARDC Policy Statement No. 80, defined class categories for projects, resolution of conflicts, and methodology for requesting test facilities and assignment of test projects.[50] As of early May 1953, NACA issued a very similar formal policy for use of its Unitary wind tunnels.[51]

At the time of ARDC's issuance of a use policy for the AEDC, the installation approached initial operational status. Much construction continued late into the decade, nonetheless. (In December 1952, the ETF was 69 percent complete. The GDF was 15 percent complete and the PWT 17 percent.)[52] *Engineering News-Record* ran a descriptive article on progress toward the ETF, GDF, and PWT, the three key test facilities of the 1950s[53] (Plate 4). The steel-frame buildings of the ETF featured deep basements and mat foundations "reminiscent of those of a power plant," with its three test chambers planned as extensible to lengths of 90 feet. To provide supersonic gas velocities for short periods in one of the "E" tunnels (later named Tunnel C and Tunnel E), the AEDC augmented the three main buildings of the GDF complex. Engineers designed a 4,000 pounds per square inch (psi) pressure tank in two parts: a welded laminated pipe 736 feet long, three feet in interior diameter, 4.87 inches thick and a welded steel vacuum sphere 72.5 feet in diameter with steel plates 1.25 inches thick. A flexible nozzle varied the opening of the 12-inch square E-1 tunnel (later named Tunnel E) (see Plate 2). Personnel could evacuate the vacuum tank to nearly 0.1 psi absolute, while they could compress the air in the pressure tank to a weight of 50 tons. Tunnel E, with the flexible nozzle, was the pilot tunnel for the GDF. This wind tunnel began operations in February 1953. Tunnel E was the site of the first purely developmental test at the AEDC, one for the Falcon guided missile in September.[54]

For the PWT, *Engineering News-Record* noted that the 35-foot diameter, 240-ton compressor rotor was to be the "largest piece of rotating equipment in the world." The PWT would feature two four-legged, closed-circuits of four wind tunnels by 1961. The PWT tunnels included a 16-foot transonic tunnel (Tunnel 16T), a 16-foot supersonic tunnel (Tunnel 16S), a four-foot transonic tunnel (Tunnel 4T), and a one-foot transonic tunnel (Tunnel 1T). Tunnel 1T was a 1/16th scale model prototype for Tunnel 16T and was the very first test facility completed at the AEDC. ARO personnel designed Tunnel 1T using German captured equipment. The tunnel was also known as PEEWEE (Building 1416), and had some operational capability as of late October 1952. ARO submitted a proposal in spring 1952 for SUPERWEE, a 1/16th scale model for Tunnel 16S. SUPERWEE (Building 760) was operational in late January 1955.[55] The support and administration buildings, as well as generic infrastructure for the AEDC, were nearly complete as of spring 1953, including the dam, primary and secondary reservoirs, and the two pumping plants with their distribution systems. (The primary administration and engineering structure for the AEDC is Building 100.)[56] The initial personnel for the AEDC moved to the installation site from their temporary quarters at the William Northern Field in Tullahoma in 1953.[57] The Arnold and NACA Ames wind tunnel complexes were comparable state-of-the-art facilities, but sustained different test functions.

Testing at the AEDC began on 30 June 1953, with a 0.03-scale model of the Bomarc guided missile in PEEWEE. Other tests went forward while construction continued at the center. From mid-1953 through 1955, testing was varied. In Tunnel E-1 of the GDF, teams ran tests for the Falcon and the AGARD guided missiles, the Redstone ICBM, and the XF (experimental fighter)-105 / F-105 aircraft.

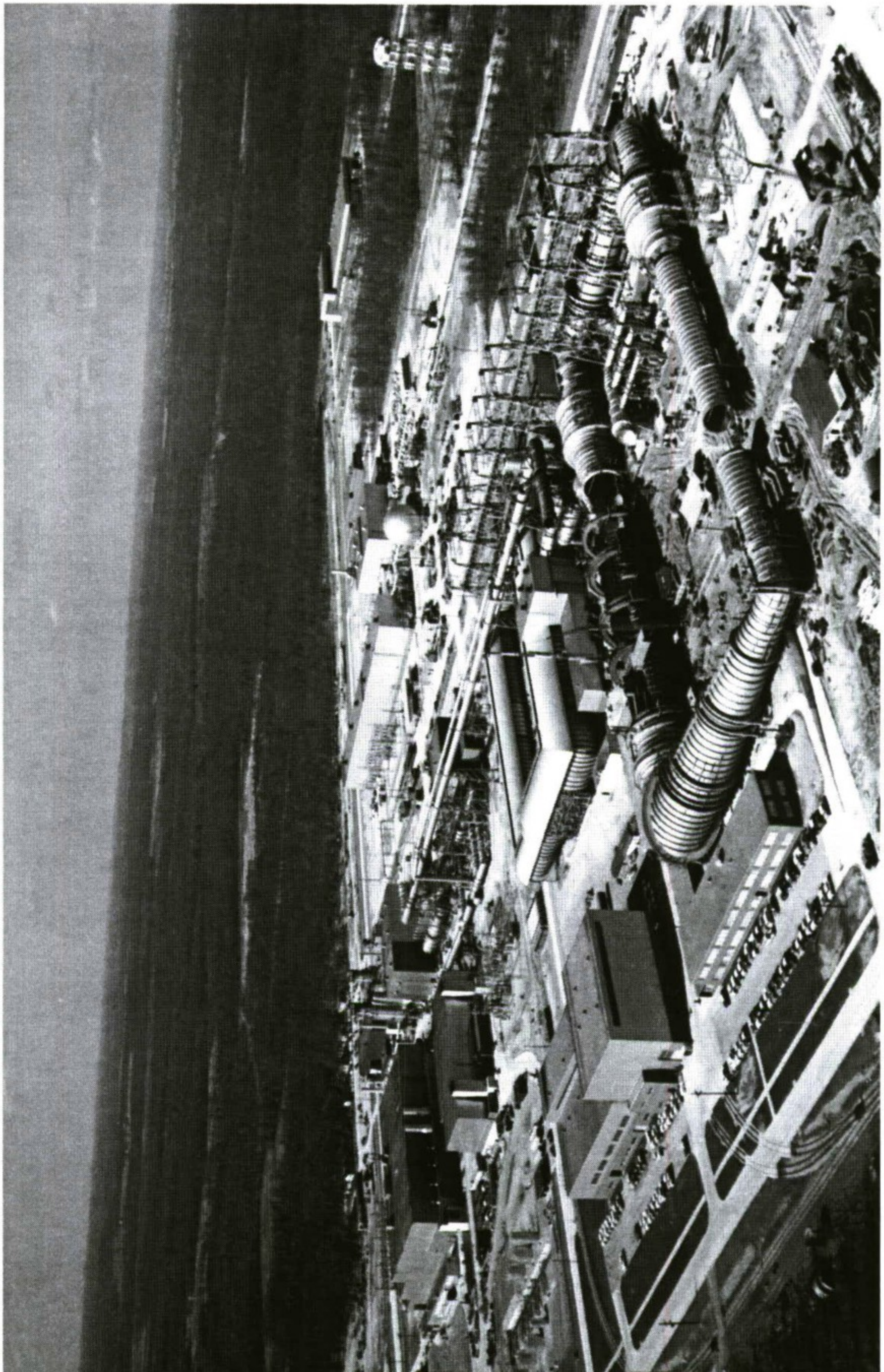

Plate 4: Arnold Engineering Development Center. Aerial view of 1958. Courtesy of Public Affairs, Arnold Engineering Development Center.

Tests in the ETF included ones for the J47, J73, and J51 turbojets, the XRJ Ramjet (for Bomarc), turbojet engines for the F-102 and F-105, and the B (bomber) -58 engine. The AEDC also oversaw outdoor run-ups of the J47-GE-17 engine for the B-47 and tests for the Hawk guided missile.[58] In August 1955, construction management for the AEDC changed sharply, with the Air Force ceding the split duties of itself and the Corps of Engineers fully to the Corps. Numerous construction contracts were underway however, with Sverdrup & Parcel retained in the leading role. The Air Force contracted for a high-altitude armament test cell in 1955 (and subsequently transferred the project to the Corps). The High Altitude Armament Test Cell augmented the ETF. The facility was under construction before the close of the year in the T-5 test bed area. The armament test cell of the middle 1950s featured a seven-foot long test bay, three by three feet in cross section. The test cell varied in diameter from five to seven feet along its 250-foot length (Plate 5).

> One side of the test section was formed by the target, which would be a typical gas tank installation from a wing or fuselage, and which tank would have a capacity of approximately 100 gallons of fuel. The target would be fired on with 50 caliber ammunition and 20 to 30 millimeter high explosive rounds of ammunition. ...Testing would be possible under maximum conditions of pressure (altitude 0 to 60,000 feet, temperature ranging from –90 degrees Fahrenheit to 660 degrees Fahrenheit, and at Mach numbers from 0 to 0.85).[59]

The High Altitude Armament Test Cell foreshadowed the 1,000-foot hyperballistic Range G armament test facility of 1963-1965 (Building 678), erected as a part of the GDF complex (Plate 6). Testing in the three main facilities of the 1950s—the ETF, GDF, and PWT—continued throughout the Cold War and included efforts for the Air Force, Army, Navy, and NASA, as well as for industrial and university contractors. Air Force and Navy aircraft tests ranged from ones for engines to scale-model tests of stores (attached fuel tanks, bombs, rockets, and guided missiles) separation (Plate 7). All three military services tested a wide variety of missiles and their components, from the guided and artillery missiles of the middle 1950s to the ICBMs and SLBMs of the 1960s-1980s. NASA tested its space capsules and components of capsules, as well as its lunar craft, multistage launch vehicles, and the space shuttle (Plate 8). Air Force missions related to space included those for sounding rockets, balloon flight, the Dyna-Soar program, satellites, and a manned orbiting laboratory. Predictably, the AEDC advanced in its testing capabilities as more sophisticated needs arose. As of the later 1950s, ARDC expanded test facilities at the AEDC coincident with the transition from NACA to NASA, the space race with the Soviet Union, and the nuclear weapons escalation of the period. In late October 1959, the Air Force renamed the GDF the von Karman Gas Dynamics Facility in honor of Dr. Theodore von Karman, then Chief Scientific Advisor to the Air Force.[60]

ARDC began adding rocket engine test facilities at the AEDC as of 1956 as an adjunct to the ETF (subsumed within the 500-series buildings). The AEDC incorporated a rocket engine test stand (Building 561) and its control center (Building 560) into the new construction. Building contractors transferred the test stand, which initiated the "J" test cell series as the J-1 test cell, to ARO as of the end of December 1957.[61] As of 1958, ARO personnel managed tests for solid propellant rockets for the third stage of a space vehicle and for satellites—the first tests for rockets of this size in the ETF. For these tests, the AEDC relied on use of the T-3 and T-4 test cells in the ETF. The T-1 test cell also supported rocket engine firing tests for the Atlas ICBM this same year.[62] As of the end of December 1958, building contractors began transferring the J-2 test cell to the Air Force, augmenting the gradual expansion of the large rocket test cells for ICBM and space-launch testing at the AEDC.[63] By mid-1959, the Kaminer Construction Corporation received the contract to erect the J-3 vertical rocket test cell. ICBM and space-launch testing continued to accelerate as 1960 approached. For the Minuteman ICBM, personnel conducted about 150 firing tests for the solid propellant rockets of the

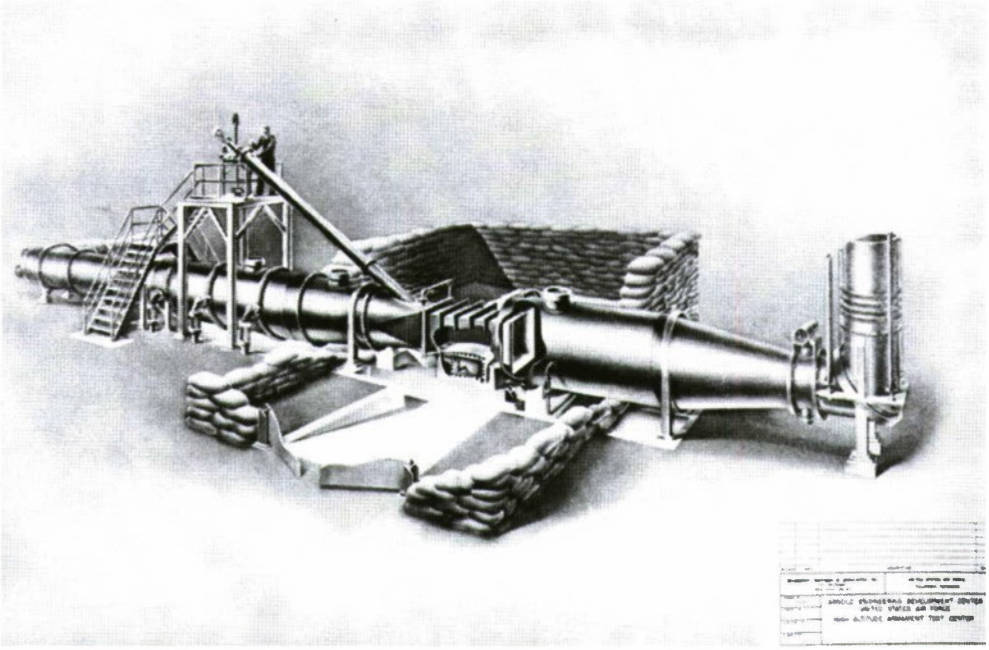

Plate 5: **High Altitude Armament Test Cell, Arnold Engineering Development Center, 1955. In *History of the Arnold Engineering Development Center 1 July – 31 December 1955*, volume I.**

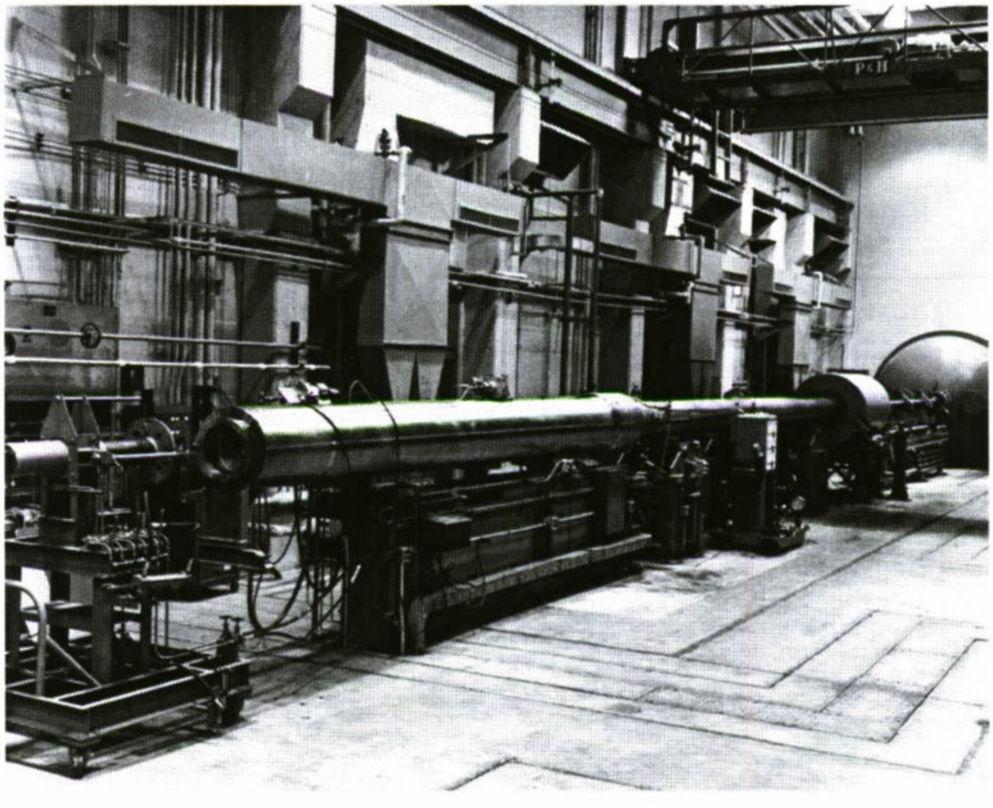

Plate 6: **Range G Hyperballistic Test Facility (Building 678), Arnold Engineering Development Center, 1965. Courtesy of Public Affairs, Arnold Engineering Development Center.**

Plate 7: **Scale-Model Stores Studies for the A-10 in the Four-Foot Transonic Wind Tunnel, Arnold Engineering Development Center, 1978. Courtesy of Public Affairs, Arnold Engineering Development Center.**

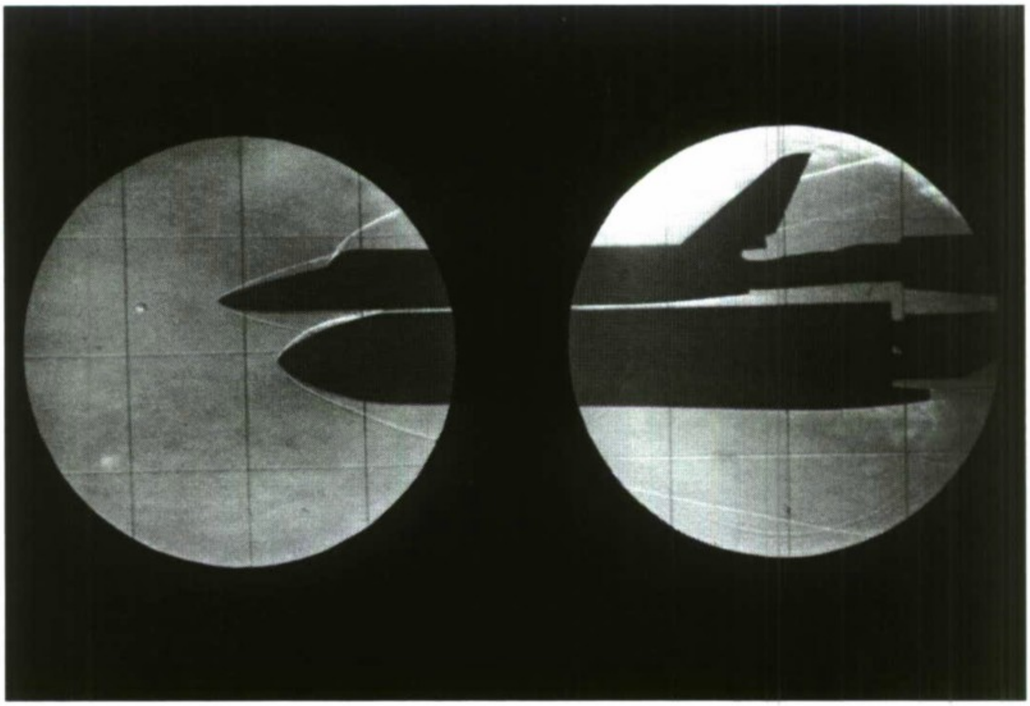

Plate 8: **Schlieren (High-Speed Airflow) Photograph. Two-Percent Model of NASA Space Shuttle Orbiter with External Fuel Tanks. In the Gas Dynamic Facility, Arnold Engineering Development Center, 1971. Courtesy of Public Affairs, Arnold Engineering Development Center.**

three stages of the developmental missile, using the ETF test cells.[64] In June 1960, personnel fired two full-scale third-stage rocket motors for the Minuteman in the J-2 test cell.[65] As of August 1960, the formal designation of the ETF, combined with its J-series test cell addition, changed to the Rocket Test Facility (RTF). The J-3 test cell (Building 890) transferred to ARO the same month.[66] The AEDC added two more test cells through the middle 1960s, the J-4 and J-5—the center's largest high-altitude rocket test cells, which were separately designated the Large Rocket Facility in 1966 (today, subsumed within Buildings 517 to 569 as primary and support structures).

AEDC's large rocket test cells were of both vertical and horizontal type. The J-3 and J-4 test cells were vertical, while the J-5 was horizontal. (Vertical configuration was originally for accommodation of liquid fuel rockets.) The J-4 test cell was of adjustable height, "for initially testing Rocket Engines up to 500,000 lbs thrust, under simulated altitude conditions."[67] Designed by Sverdrup & Parcel on the basis of conceptual layouts developed by the Air Force, the J-4 test cell (Building 530) remains the largest, high-altitude rocket test cell in the world.

> Engines are mounted on the vertical thrust stand in the cell above ground level. For J-4 the exhaust gases are directed from the test cell through a 20-foot diameter diffuser located at the entrance to a 250-foot deep, 100-foot diameter underground excavated cooling chamber, which cools the gases before being pumped out to atmosphere by the ETF rotating machinery. ...Water is used to cool and scrub exhaust gases...spray bars inject up to five hundred thousand gallons of cooling water per minute into the exhaust gases coming from the twenty-foot diameter diffuser. A sombrero-shaped deflector at the bottom turns the exhaust upward along the cooling chamber walls. The dry gas is then pumped to atmosphere...[68]

The J-4 test cell allowed engineers to examine full-scale "large liquid- and solid-propellant rocket engines in their natural vertical flight position." As AEDC project manager Alton C. Morris noted in May 1961: "This will allow detailed study of phenomena inherent in a missile...without expending the missile itself—a capability heretofore nonexistent."[69] The J-5 test cell (Building 522), 50 feet long with an internal diameter of 16 feet, tested rockets at simulated altitudes to 100,000 feet. In November 1985, motor failure blew up and destroyed the J-5 test cell during the test of a Peacekeeper Stage III motor. AEDC rebuilt the J-5, with resumed operations in December 1986.[70] (The J-5 test cell had previously suffered extensive damage in 1971 during an Army Advanced Ballistic Missile Defense Agency solid rocket motor test.[71]) The J-series test cells operated much like ICBM launch complexes, with blockhouse control centers (Building 520 for the J-4 and J-5 test cells) and large below-ground components.[72] As envisioned in 1962, the AEDC planned to expand the J-series test cell area to include nine large test cells, with blockhouses (Plates 9-13). At the end of the Cold War in November 1989, AFSC initiated a three-year contract for construction of the J-6 test cell (Building 2124). The J-6 test cell was a very large and segregated horizontal test cell facility for continued testing of the Peacekeeper and its follow-ons.[73]

By the end of the 1950s, testing for space missions had also grown in urgency, with ARDC selecting the AEDC to prepare the operating and design requirements for a Large Space Environment Test Facility as of late June 1959. The next month, the AEDC established a Space Environments Simulation Office at the installation and initiated the Phase I engineering study for the test facility. An Ad Hoc Panel of the SAB reviewed the Phase I study in December. The AEDC set up an Aerospace Environments Project Office as of mid-January 1960. Planning expanded to include two environmental space test chambers, with the second officially referenced as Project 7778 for a Weapons System Environmental Chamber. In March 1960, the Air Force named the environmental

space chambers the Aerospace Systems Environmental Chamber, Mark I, and, the Aerospace Systems Environmental Chamber, Mark II. ARDC considered the Mark 1 to be an "interim" chamber and the Mark II to be the final large space environmental facility. (An austere version of the Mark II was still in discussion as late as 1965 for $28 million, but the facility was never constructed.[74]) ARDC approved moving forward with the Mark 1 before the close of the month, with a prebidders conference at the AEDC in late April. In July, the first design criteria contract for $98,000 went to the Radio Corporation of America (RCA) of Camden, New Jersey. ARDC also awarded RCA the final Mark 1 design contract (for $466,720) in September.[75]

The Mark 1 space chamber (Building 1075) project was of high profile and importance. The Directorate of Civil Engineering at Headquarters Air Force monitored RCA's design closely and chronicled repeated discussions in the Directorate's unit histories of 1961-1968. The Mark I was to "permit the simulation of outer space to altitudes of several hundred miles."[76] RCA designed the facility as "a large vacuum chamber which will have the capability of testing full scale satellite vehicles under simulated environmental conditions of space pressure, temperature, solar radiation, and vibration."[77] RCA submitted its initial completed drawings for the Mark 1 in March 1961. By July, the working estimate for construction costs was $16.643 million and in late October the 87th Congress passed Public Law 302 to appropriate $17.5 million for the Mark 1 Aerospace Systems Environmental Chamber.[78] Many specialized firms subcontracted to RCA for components of the Mark 1. Burns & Roe of New York (today, New Jersey) handled the design of the building that housed the chamber, its refrigeration equipment, and its multilevel preparation, instrumentation, and observation units. The architectural-engineering firm completed their drawings between August and October 1961.[79] With respect to its work for the Air Force, Burns & Roe was known best for its design of Combat and Direction Centers for the Semi-Automatic Ground Environment (SAGE)—the major air defense system of the late 1950s (see Volume 1, Part IV). The firm was more widely known for innovative power plant engineering. The solar simulator for the Mark 1 was an add-on to the original contract with RCA. The simulator was the feature which would take the total cost for the test facility to $18.132 million.[80] The Corps of Engineers transferred the Mark 1 to the AEDC in December 1965, following its acceptance of the Mark 1's engineering laboratory in November 1964 and the facility's trial pumpdown in mid-April 1965. In early January 1966, tests for Goodyear's inflatable crew transfer tunnel were among the very first in the operational Mark 1.[81] Additional enhancements to the Mark 1, including a cryogenic system, raised the final cost for the Aerospace Systems Environmental Chamber at the AEDC to $19.4 million at project close-out in late 1968 (Plates 14-15).[82] Of note, NASA also commissioned a space environment facility at its Goddard Space Flight Center in Greenbelt, Maryland, simultaneous with the Air Force Mark I project. In August 1961, NASA contracted for two space chambers at Goddard for the checkout and testing of large spacecraft. NASA's space environment facility featured a multistage pumping system to achieve vacuum conditions, and was able to simulate both the coldness of outer space and the direct heat of solar radiation. The NASA space chambers were operational by late 1962, and probably served as a model for some components of the Mark I at the AEDC.[83]

During the later 1960s and into the 1980s, AEDC added facilities, with the Aeropropulsion Systems Test Facility (ASTF) the most significant. The AEDC had used the World War II airfield in Tullahoma during the 1950s and 1960s, even as planning for a new runway had been in place from the installation's beginnings in 1951. The Office of the Secretary of Defense did not approve the runway until the end of 1964—to permit air delivery of test components. The AEDC initiated runway construction in early 1968.[84] In late 1964, construction began for the University of Tennessee Space Institute near the AEDC at an independent site, in a cooperative venture between the University of Tennessee and the AEDC (see Volume 1, Part II and Volume 1, Plate 9). The next year, the Tennessee Space Institute and the University of Aachen, Germany, signed a student-faculty agreement, and in 1966 the institute opened.[85] The Air Force also added a "chicken gun" in 1972, as

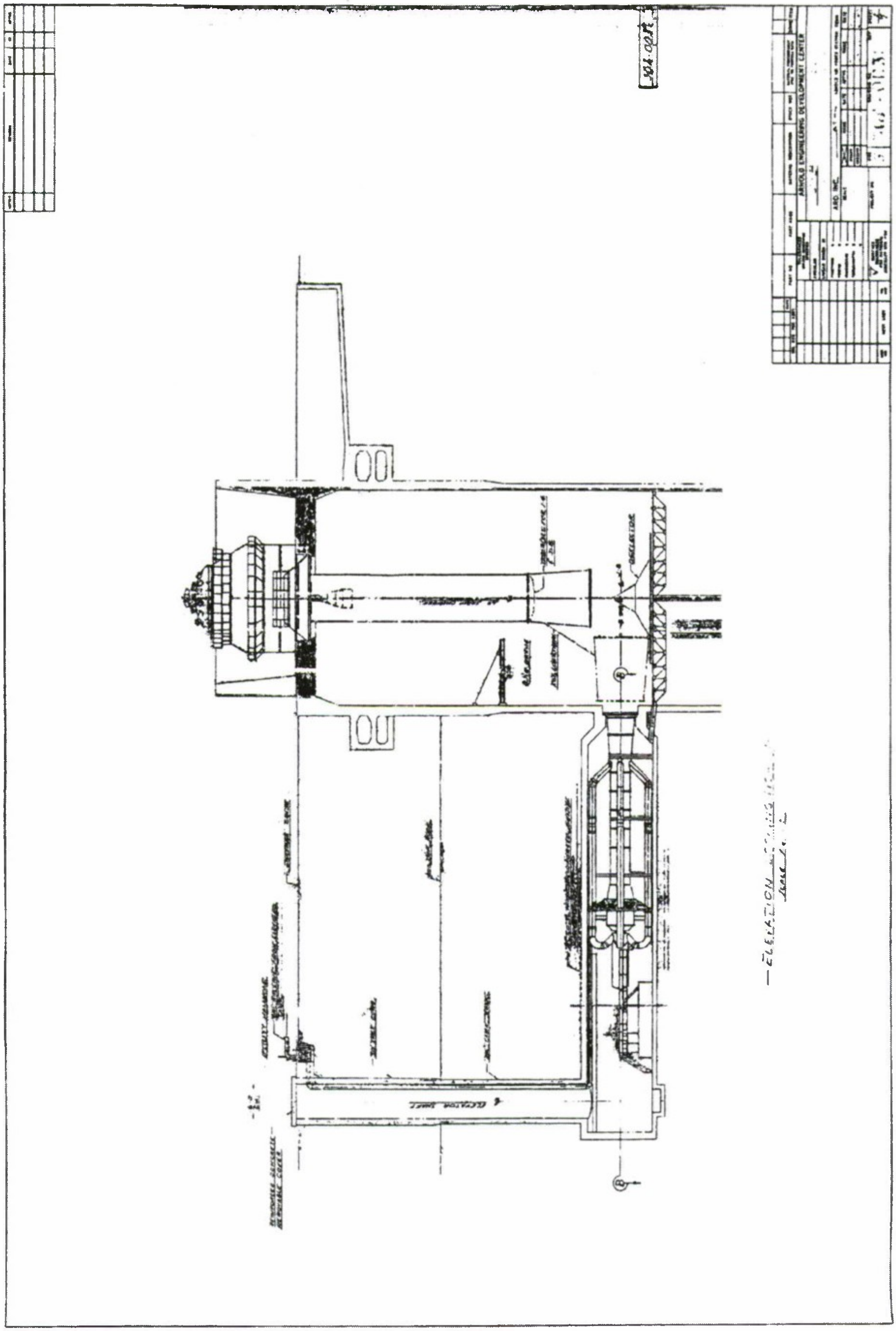

Plate 9: J-3 Test Cell (Building 890), Engine Test Facility (Rocket Test Facility), Arnold Engineering Development Center, 1959-1960. Courtesy of Civil Engineering, Arnold Engineering Development Center.

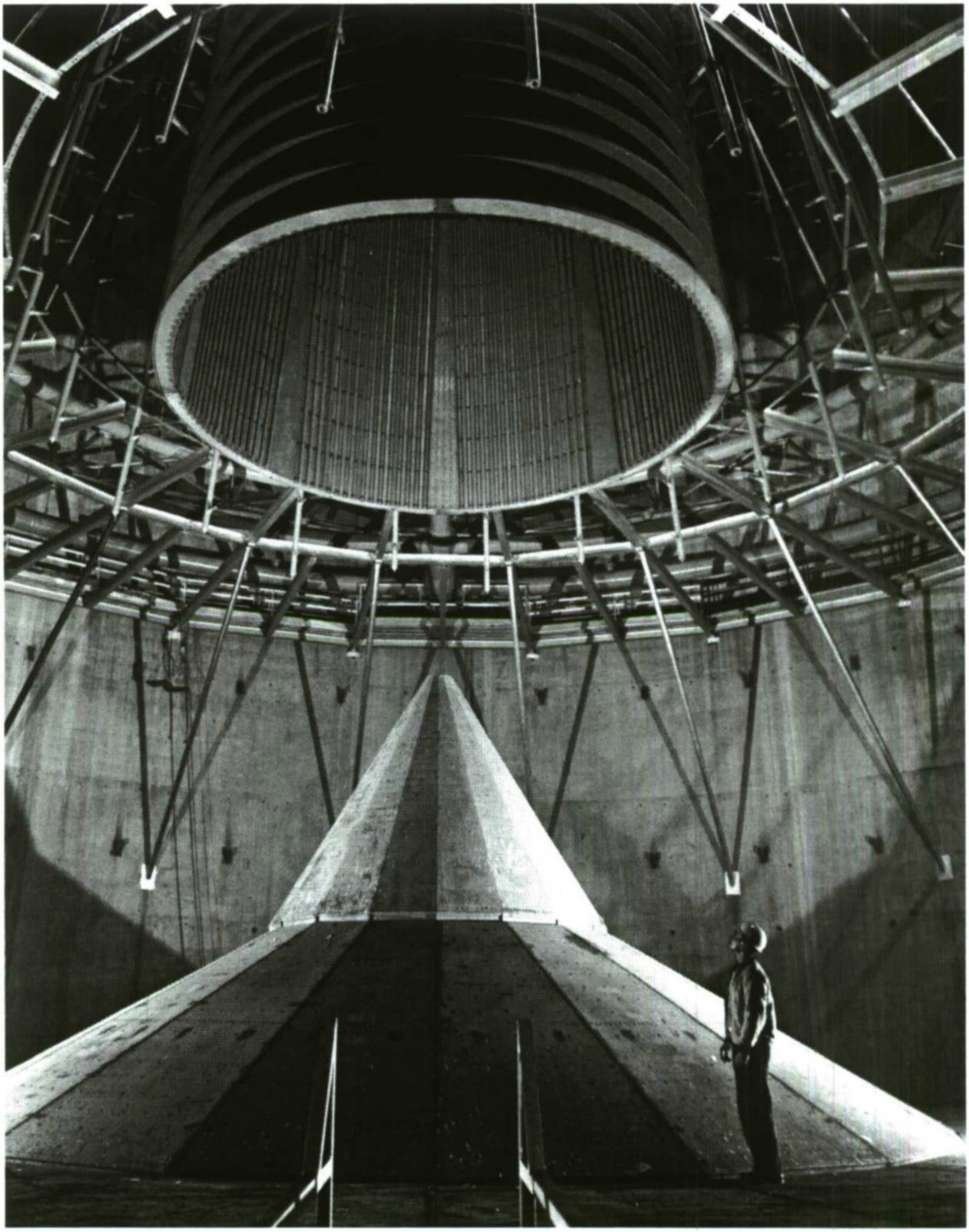

Plate 10: J-4 Test Cell (Building 530), Large Rocket Test Facility, Arnold Engineering Development Center, 1964. Courtesy of Public Affairs, Arnold Engineering Development Center.

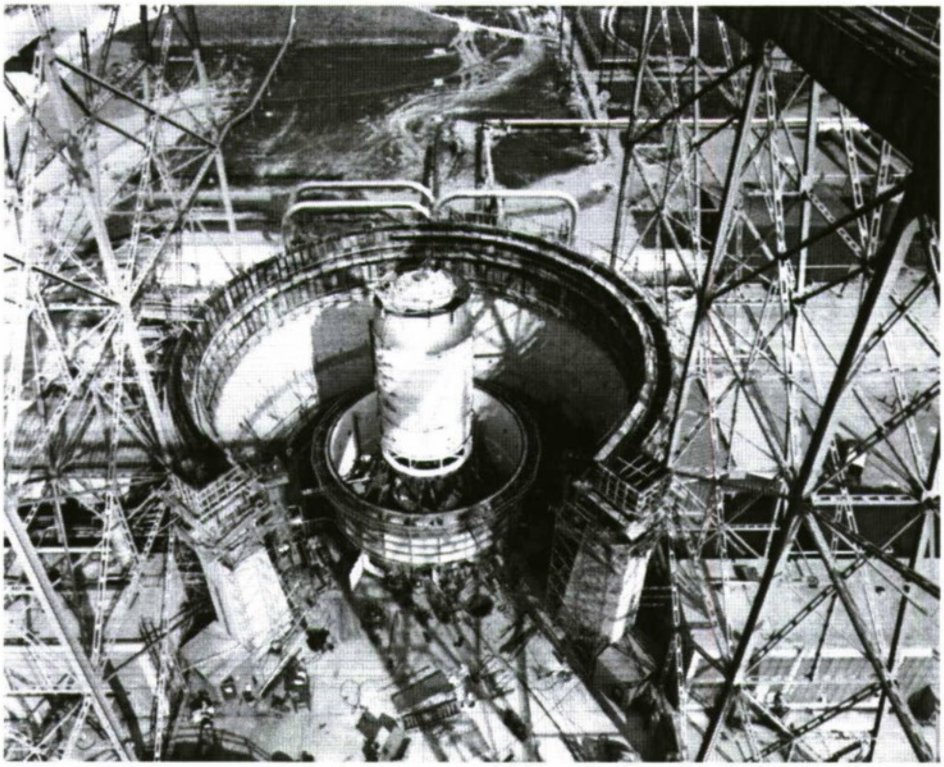

Plate 11: **Saturn IVB in the J-4 Test Cell (Building 530), Large Rocket Facility, Arnold Engineering Development Center, 1966. Courtesy of Public Affairs, Arnold Engineering Development Center.**

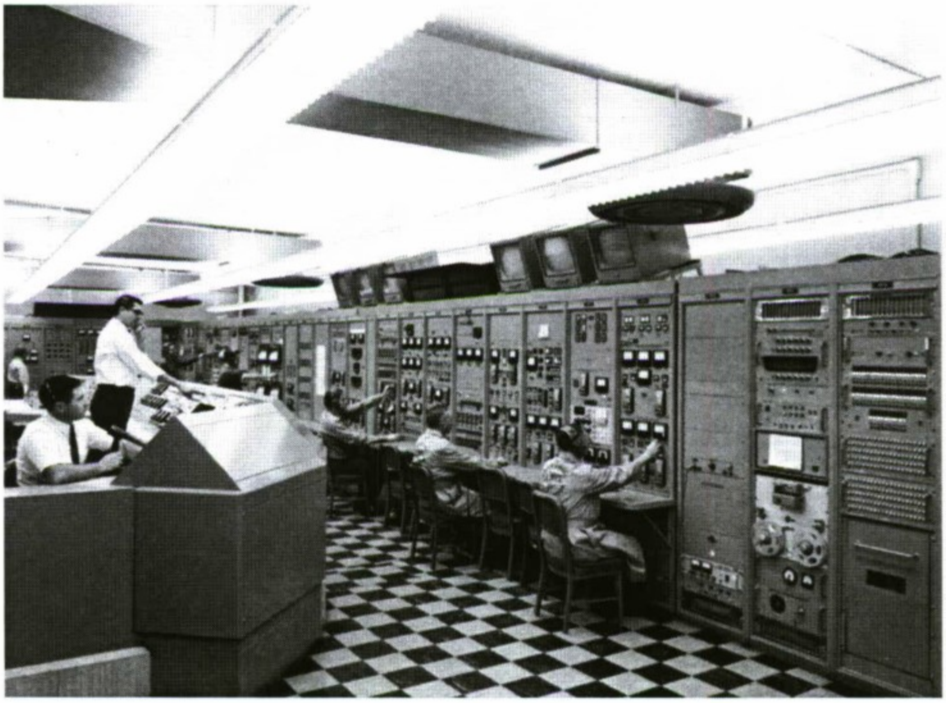

Plate 12: **Control Room in the Blockhouse for the J-4 and J-5 Test Cells (Building 520), Large Rocket Facility, Arnold Engineering Development Center, 1969. Courtesy of Public Affairs, Arnold Engineering Development Center.**

Plate 13: Saturn IVB in the J-4 Test Cell (Building 530), Large Rocket Facility, Arnold Engineering Development Center, 1966. Courtesy of Public Affairs, Arnold Engineering Development Center.

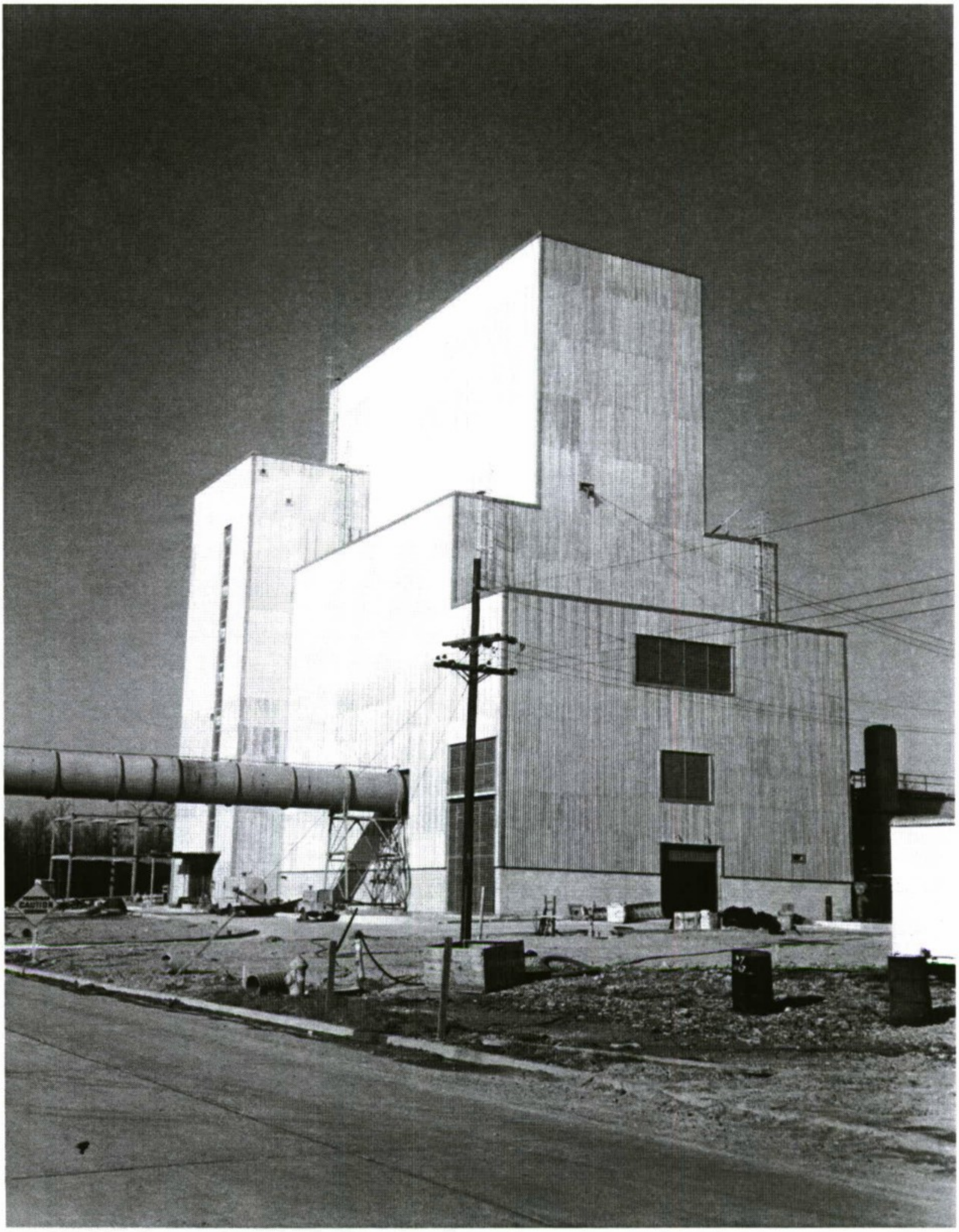

Plate 14: Burns & Roe. Mark I Aerospace Systems Environmental Chamber (Building 1075), Arnold Engineering Development Center, 1964. Courtesy of Public Affairs, Arnold Engineering Development Center.

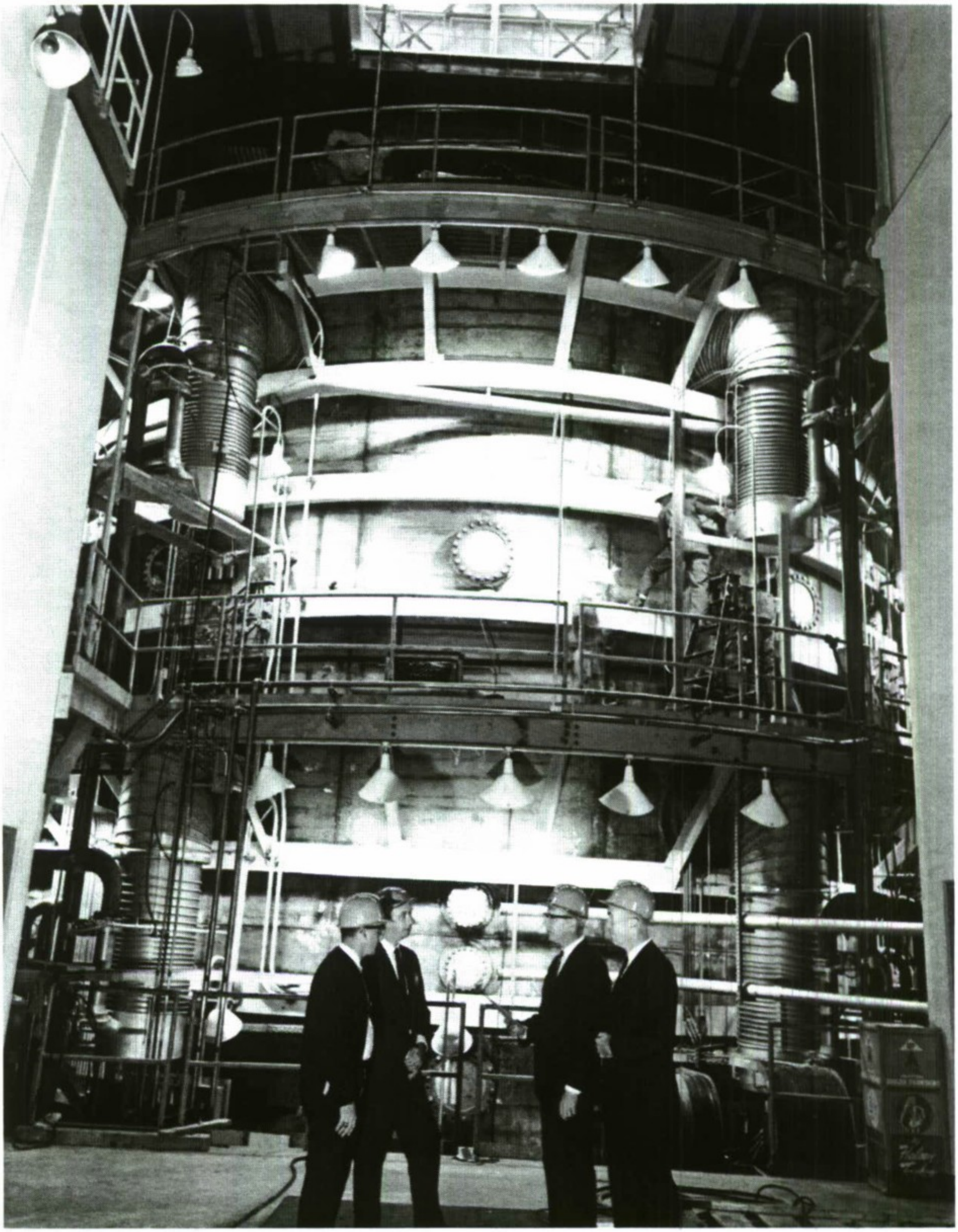

Plate 15: Radio Corporation of America (RCA). Mark I Aerospace Systems Environmental Chamber (Building 1075), Arnold Engineering Development Center, 1964. View of interior chamber. Courtesy of Public Affairs, Arnold Engineering Development Center.

an augmentation of the ballistics testing at the G ranges of the GDF. The test facility simulated the impact of birds against the windshields of aircraft using chicken carcasses hurled at speeds up to 700 miles per hour. The chicken gun assisted engineers to "develop transparent materials that, although light weight and optically suitable, will withstand high impact forces without breaking, shattering or excessive bending."[86] The multi-building ASTF was without doubt, however, the key expansion of test capabilities at the AEDC during the later Cold War.

Engineers designed the ASTF (the 900-series buildings) as part of the ETF. The facility featured a realistic testing environment for full-scale propulsion systems of increasing complexity. Each of its two test cells was 28 feet in diameter and 85 feet long. (The ETF's next largest test cell was 20 feet in diameter and 60 feet long.) The ASTF could simulate flight conditions to altitudes of 100,000 feet at speeds to Mach 3.8, for engines of up to 100,000 pounds of thrust. The ASTF required both extreme cooling and heating. For a flight environment of high-altitude and low-speed missions,

> [t]wo large coolers and enough refrigeration equipment to cool 6,000 average American homes are available to dry and cool the air to minus 20 degrees Fahrenheit. Then the air can be passed through five expansion turbines to cool it even further to as low as minus 100 degrees Fahrenheit...

Very large air heaters "raise the temperature of the airflow to a maximum of 1,020 degrees Fahrenheit" to simulate supersonic flight conditions.[87]

The ASTF was a $625 million construction project—one of the largest in Air Force history. During November 1972, the Air Force selected the engineering firm of Daniel, Mann, Johnson and Mendenhall (DMJM) of Los Angeles for the job.[88] DMJM had designed the Atlas space launch complex at Cape Canaveral in the early 1960s and had substantial experience in complex aerospace engineering projects. Divided into four phases, DMJM's design for ASTF occupied 1973 through 1976.[89] Congress approved full funding for ASTF construction in May 1976. The AEDC established the ASTF project office as of mid-January 1977 and broke ground in August.[90] The ASTF was a National Test Facility. American defense agencies consider the facility of parallel essential character to the nation as the 80- by 120-foot wind tunnel at the NASA Ames Research Center at Moffett Field, California, and to the National Transonic Facility at NASA's Langley Research Center in Virginia (Plate 16). Workers completed construction for the ASTF in July 1984, with initial operational capability as of September 1985.[91]

The AEDC added one final complex of note immediately after the conclusion of the Cold War—the Decade Radiation Test Facility (Building 1088). Decade is a nuclear weapons effects simulator for missile and space systems testing. Sponsored by the Defense Nuclear Agency (DNA), the Decade test facility uses hot and cold x-rays, as well as prompt gamma radiation. Decade also has debris gamma and beta radiation capability and an "advanced test bed consisting of a cryogenic vacuum chamber with infrared scene generation and nuclear clutter simulation." Decade was under initial construction as of 1994, with operational capability during 1999-2000.[92] Decade joins the family of historic nuclear effects simulators, including those of Hermes I, II and III, Aurora, Saturn, Double-Eagle, Blackjacks 3 and 5, Pithon, Phoenix, Casino, Gamble II, and Owl. The AEC (today's Department of Energy [DOE]), the Defense Atomic Support Agency (DASA) (subsequently, DNA, and today's Defense Atomic Support Information Activity Center [DASIAC]), their military contractors, and American universities began to require simulators that tested weapons systems in a nuclear effects environment after the Limited Test Ban Treaty went into effect in 1963. The treaty prohibited aboveground nuclear weapons testing (see Volume I, Part I). Before Decade's installation at the AEDC, the other center for this type of sophisticated testing within ARDC had been the Air Force Weapons Laboratory at Kirtland Air Force Base in New Mexico (effectively coupled with the

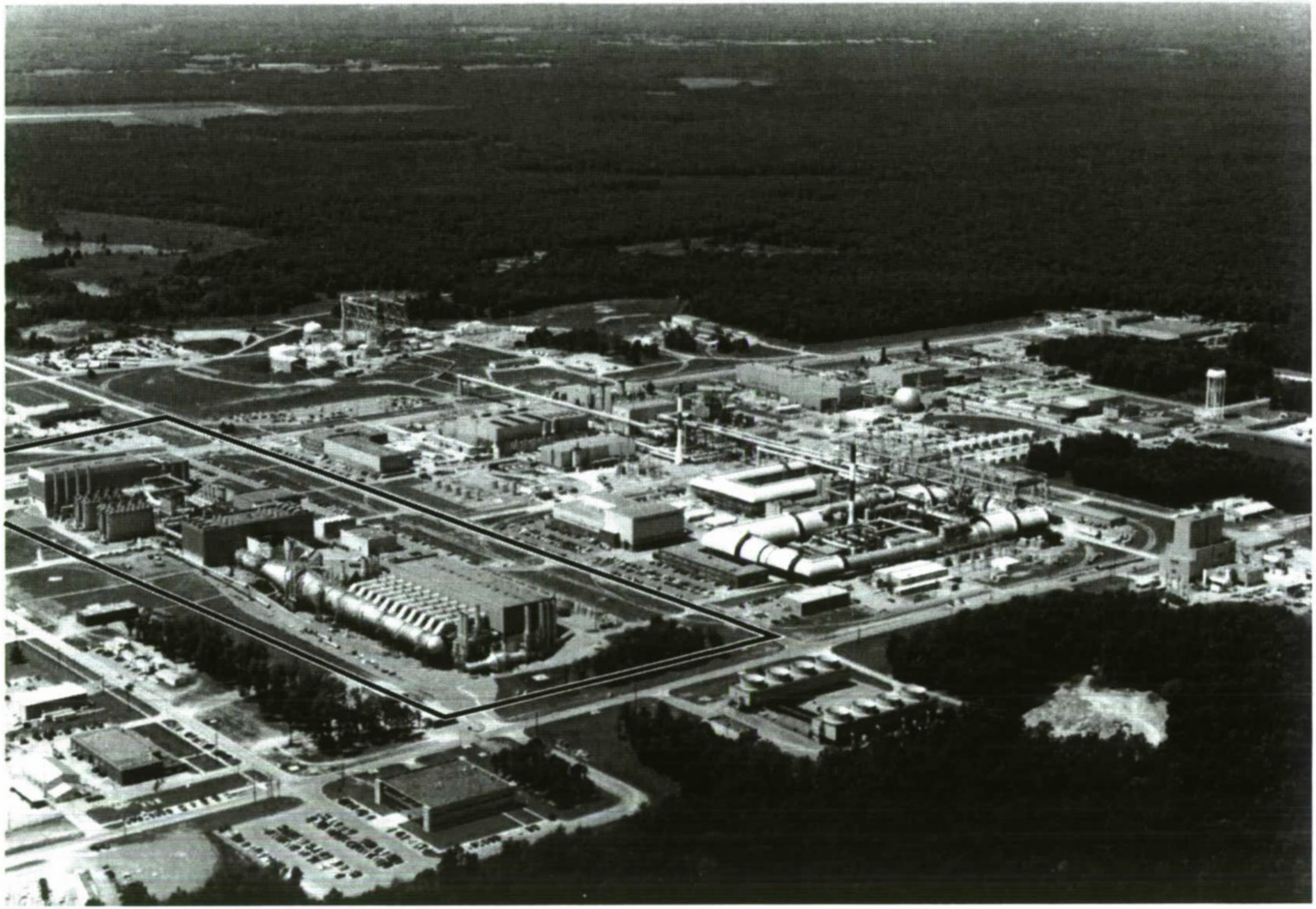

Plate 16: Daniel, Mann, Johnson & Mendenhall (DMJM). Aeropropulsion Systems Test Facility (ASTF), Arnold Engineering Development Center, 1987. Aerial view. Courtesy of Public Affairs, Arnold Engineering Development Center.

simulators operational at the neighboring Sandia Laboratories), and, as of the middle 1980s, the Pulserad Little Mountain Facility at Hill Air Force Base in Utah—the latter a facility for standardized hardening tests of Air Force equipment parts pulled out of stockpile (see Volume II, Chapters 6 and 8). Decade's equipment reused capacitors from the Aurora nuclear effects simulator at the Army Research Laboratory in Maryland. Aurora was operational in 1972. Physics International designed both Aurora and Decade. Other locations considered for setup of Decade included the Army Research Laboratory (as a replacement for Aurora) and the White Sands Missile Range in New Mexico. The Navy began testing Decade at the AEDC as of the middle 1990s[93] (Plate 17).

Key Associated Architects and Engineers

Architectural and engineering firms of national note who participated in the planning for the AEDC test complex during the Cold War, or who are known to have designed structures of high individual significance at the installation, include:

- Burns & Roe, of New York (Oradell, New Jersey);
- Daniel, Mann, Johnson, and Mendenhall (DMJM), of Los Angeles; and,
- Sverdrup & Parcel, of St. Louis.

Each of these firms occupies a prominent place in engineering design for the Department of Defense and for the Air Force.

Plate 17: Physics International. Decade Radiation Test Facility (Building 1088), Arnold Engineering Development Center, 1995. Courtesy of Public Affairs, Arnold Engineering Development Center.

Burns & Roe

Burns & Roe handled the design of the building for the Mark 1 Aerospace Systems Environmental Chamber under the RCA master contract. Founded by Ralph C. Roe in 1932, Burns & Roe established itself as a noteworthy designer of power plants. The firm pioneered engineering for nuclear power plants, for facilities showcasing advanced energy technologies, and for aerospace projects, including first-of-a-kind structures such as the Mark 1. Burns & Roe is also known for the design of uranium ore processing facilities and for engineering associated with the handling of military chemical munitions. For the Department of Defense, the firm has carried forward work for computer centers, communications and electronics networks, radar systems (including the SAGE Combat and Direction Centers), missile support and testing facilities, vacuum chambers, wind tunnels, and specialized research and development sites.[94]

Daniel, Mann, Johnson, and Mendenhall (DMJM)

DMJM, a partnership of Phil Daniel, Art Mann, Ken Johnson, and Irv Mendenhall, originated in 1946 in Santa Maria (north of Los Angeles) as a collaboration between Daniel, Mann and Johnson. Two of the firm's members had met during World War II in the Pacific, where Art Mann was in the Corps of Engineers on Saipan. Irv Mendenhall worked as a consulting engineer for the three men almost from the start, after joining the firm in 1950. DMJM's first jobs were designing schools in Southern California. By the middle 1950s, DMJM was handling many military contracts, with considerable work overseas (particularly in Japan). The firm planned, designed, or rehabilitated upwards of 30 bases in Great Britain, Europe, and Asia. For these projects, DMJM developed underground fuel storage, high-speed refueling equipment, maintenance shops, storage facilities, housing, and recreational buildings, and also lengthened or straightened existing overseas runways. By 1956, three-quarters of DMJM's work was directly for the Air Force. The firm won the first consultant contract issued by Headquarters Air Force to develop definitive drawings for its standard structures. (Other individual firms designed many of the technical buildings within the "standard" structures group, with this work overseen by ARDC and its predecessor Air Materiel Command. DMJM redrew these designs to incorporate sequential modifications, essentially updating the files [see Volume I, Part III].)

Missiles infrastructure design and engineering evolved as a DMJM specialty. The firm was responsible for much of the early launch complex work at Cape Canaveral (the major test location for the Air Force Missile Test Center at Patrick Air Force Base) from 1955 into the early 1960s, as well as for the design and engineering of the Thor IRBM launch complexes at Vandenberg in 1957. At Patrick, ARDC also commissioned DMJM in 1956 to engineer the liquid oxygen (LOX) manufacturing facility that supported all of the missile programs at the base. During this period, the firm additionally designed Atlas ICBM test facilities for Convair in San Diego, including a static test stand, a missile components test stand, a control blockhouse, and an office-laboratory complex. For North American Aviation's Rocketdyne Division, DMJM engineered the LOX plant and a group of rocket engine test stands for IRBM and ICBM work at Santa Susana Canyon north of Los Angeles (see Volume I, Plate 42). One of these test stands featured a vacuum chamber to simulate altitude conditions. For North American Aviation's Autonetics Division in Downey, the firm designed a 230,00-square-foot dust-free structure—essentially an oversized clean room. This unusual facility accommodated the development, engineering, and manufacture of automatic navigation systems, and immediately abutted one of the discontiguous sites of today's Los Angeles Air Force Base[95] (see Volume II, Chapter 9). Later in its history, DMJM designed and engineered projects as radically different from one another as the Bay Area Rapid Transit System (BART) in the San Francisco Bay Area in the late 1960s and 1970s, and the Fermi National Accelerator Laboratory in Batavia, Illinois (the latter, as part of a consortium). The Fermi proton accelerator was the world's largest such

facility when built. DMJM's design and engineering for the ASTF at the AEDC during the 1970s and 1980s was an equally notable achievement (executed in partnership with Norman Engineering). Near the end of the Cold War in 1986, DMJM won the contract for the maintenance facility and support complex for Air Force One at Andrews Air Force Base.[96]

Sverdrup & Parcel

Sverdrup & Parcel, founded in St. Louis in 1928 by Leif Johan Sverdrup (1898-1976) and John Ira Parcel (b.1878), developed both the initial site surveys and the underlying engineering for the AEDC. Sverdrup, a Norwegian, had immigrated to the United States in 1914 and subsequently attended college in Minnesota as an engineer. Dr. Parcel was a professor of structural engineering at the University of Minnesota. He was educated at the University of Illinois and had an alternate intermittent career as a bridge engineer. Leif Sverdrup also first worked as a bridge engineer. He rose to chief bridge engineer for the Missouri State Highway Department by 1927. The Sverdrup & Parcel partnership formed to engineer the Gasconade River Bridge in Missouri in 1928. The firm's early commissions focused on bridge design. During World War II, Sverdrup & Parcel engineered American military airfields in the Pacific (as of October 1941). At the request of General Douglas MacArthur, Leif Sverdrup accepted a position as Colonel in the Corps of Engineers in 1942. He continued work in the southwestern Pacific and relinquished ties to Sverdrup & Parcel during his tenure with the Army.

Dr. Parcel, running the firm in Sverdrup's absence, was a specialist in statically indeterminate structures. Late in World War II, Dr. Parcel worked on the design and engineering for two wind tunnels at Wright Field: a 10-foot wind tunnel capable of simulating the speed of sound at very high and low temperatures (augmenting an earlier 20-foot tunnel that could not simulate altitude and reached only 450 miles per hour) and a two-foot supersonic wind tunnel. Construction for the tunnels was complete in late 1945. Dr. Parcel formed a close friendship with Dr. Frank Wattendorf while working for Air Technical Service Command on the tunnels. In 1946, Sverdrup & Parcel's first major assignment after the war was the design and engineering for the AEDC. During the 1950s, the firm also designed major hydroelectric complexes. These works included most of the dams on the Columbia River in the Northwest, four dams on the Missouri River in the central United States, and the Bhumiphol Dam in Thailand. Dr. Parcel continued to publish during this decade. His second textbook, *Analysis of Statically Indeterminate Structures*, appeared in 1955.[97] Sverdrup & Parcel maintained its role in the design and engineering process at the AEDC through the J-series of large rocket test cells and the hypersonic ballistics Range G test facility of the 1960s. The firm designed two major facilities at Vandenberg Air Force Base in Southern California: the space shuttle launch complex of the late 1970s and the Rail Garrison test compound for Peacekeeper at the conclusion of the Cold War (see Volume I, Part I). Other engineering firms contributed major designs for certain later-era test complexes at the AEDC. (In all cases at the AEDC, many individual firms designed components of test facilities.)

---

[1] Arnold Engineering Development Center, *History of Arnold Engineering Development Center 1944-1951*, 3.
[2] Mission specifics and associated dates through 1977 are included in Arnold Engineering Development Center: *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, and, *Chronology of the Arnold Engineering Development Center 1 July 1970 – 31 December 1977*. Major missions after 1977 are generally included in Office of Public Affairs, Arnold Engineering Development Center, *Arnold Engineering Development Center (AEDC)*, April 1998.
[3] *History of Arnold Engineering Development Center 1944-1951*, 5.
[4] Engineering Division, Air Technical Service Command, *Proposed Air Engineering Development Center*, 10 December 1945, as printed in April 1946.

[5] "Electronic Subdivision Facilities Required for the Five Year Program," typescript filed with undated materials for the "Air Engineering Development Facilities," Air Force Historical Research Agency. Internal references to plans for a radar test building at Wright Field place the document before July 1946, with a high likelihood of early 1946.
[6] *History of Arnold Engineering Development Center 1944-1951*, 9.
[7] *Ibid*, 9-10.
[8] Air Materiel Command, *History of the Air Materiel Command 1 January – 30 June 1949*, 33.
[9] Research and Development Directorate, Headquarters United States Air Force, *Review of the Site Survey for the AEDC*, 30 December 1948.
[10] *History of Arnold Engineering Development Center 1944-1951*, 12-15.
[11] *Ibid*, 17-21; *Subcommittee Hearings on H.R. 3434, to Promote the National Defense by Authorizing a Unitary Plan for the Construction of Transonic and Supersonic Wind-Tunnel Facilities and the Establishment of an Air Engineering Development Center*, Washington, D.C., 11 April 1949.
[12] Tennessee Valley Authority, *Air Engineering Development Center Adaptability of Sites in the TVA Area*, eight-page typescript with map, May 1949.
[13] *History of Arnold Engineering Development Center 1944-1951*, 23.
[14] 81st Congress, Chapter 766—1st Session, Public Law 415 [S. 1267], 27 October 1949.
[15] *History of Arnold Engineering Development Center 1944-1951*, 23-26.
[16] *Ibid*, 33-34; Air Materiel Command, *History of the Air Materiel Command 1 July – 31 December 1949*, volume 1, 65-66.
[17] Gordon P. Saville, Deputy Chief of Staff, Development, United States Air Force, "Organizational Planning for the Air Engineering Development Division," memorandum of 24 October 1950, in Arnold Engineering Development Center, *AEDC WADC Facilities Study Group*, volume 2.
[18] *History of Arnold Engineering Development Center 1944-1951*, 34-35, 48-49.
[19] *Ibid*, 35-36, 54-55.
[20] *Ibid*, 46. The document gives the measurements for all six tunnels in "feet," but this is assumed to be an error. The pair of six-by-six and eight-by-eight tunnels are undoubtedly in "feet." Engineers interpreted the eight-by-eight-foot tunnels as too small for full-scale testing, and requested that the size be enlarged to approximately 15-by-15-foot (with the PWT the realization of this change, at 16-by-16-foot). The other two tunnels discussed, however, seem to be recorded with the "feet" measurement intended as "inches," and are assumed to have been tunnels for models testing. A size of 30 or 40 feet in diameter would have been unlike anything referenced in documents of this period, for the AEDC or elsewhere, whereas 40-by-40-inch tunnels are both of a size shipped to the United States as war-confiscated equipment, and under discussion for the GDF.
[21] Arnold Engineering Development Center, *History of the Arnold Engineering Development Center 1 January – 30 June 1952*, volume 1, 125-127, 134, 141.
[22] *History of Arnold Engineering Development Center 1944-1951*, 46-48, 51-53.
[23] Special Committee on A.E.D.C. Operation, *Report of the Special Committee on A.E.D.C. Operation* [*Markham Report*], 26 April 1950.
[24] *Ibid.*
[25] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 21.
[26] *Arnold Engineering Development Center (AEDC)*, 1998.
[27] *History of Arnold Engineering Development Center 1944-1951*, 60-64; and, email communications with David Hiebert, Historian at the AEDC.
[28] David A. Anderton, "AF Reveals Plans for Engineering Center," *Aviation Week* 55, 1 (2 July 1951): 13-14.
[29] *Ibid*; *History of Arnold Engineering Development Center 1944-1951*, 65-67.
[30] *History of Arnold Engineering Development Center 1944-1951*, 68-70.
[31] Hugh M. Arnold, "Arnold Engineering Development Center," *The Military Engineer* 43, 295 (September-October 1951): 320-321.
[32] Anderton, "AF Reveals Plans for Engineering Center," *Aviation Week*, 2 July 1951, 13-14.
[33] *History of the Arnold Engineering Development Center 1 January – 30 June 1952*, volume 1, 134.
[34] Anderton, "AF Reveals Plans for Engineering Center," *Aviation Week*, 2 July 1951, 13-14.
[35] *History of the Arnold Engineering Development Center 1 January – 30 June 1952*, volume 1, 141-142, 146.
[36] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 35, 40.
[37] Arnold, "Arnold Engineering Development Center," *The Military Engineer*, September-October 1951, 320-321.

[38] *History of the Arnold Engineering Development Center 1 January – 30 June 1952*, volume 1, 146.
[39] Arnold, "Arnold Engineering Development Center," *The Military Engineer*, September-October 1951, 320-321.
[40] Arnold Engineering Development Center, *History of the Arnold Engineering Development Center 1 January – 30 June 1951*, volume 1, 77-79, 100-101, volume 2, supporting documents and plans, and volume 3, photographs.
[41] Arnold, "Arnold Engineering Development Center," *The Military Engineer*, September-October 1951, 320-321.
[42] Office of Public Affairs, Arnold Engineering Development Center, tour of the facilities, October 2000.
[43] "Dr. Bernhard August Goethert," Appendix H in Arnold Engineering Development Center, *History of the Arnold Engineering Development Center 1 July – 31 December 1954*, narrative and supporting documents.
[44] G. M. Arnold, "Characteristics of the LFM Wind Tunnel," ACRE-52-1, 20 March 1952, in *History of the Arnold Engineering Development Center 1 January – 30 June 1952*, volume 2.
[45] Guenther Dellmeier, "Characteristics of the Yokosuka Wind Tunnel," ACRE-52-2, 4 April 1952, in *ibid.*
[46] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 41.
[47] Colonel C.K. Moore, Commander, AEDC, "Procedures for Getting Test Time Allocated in AEDC Facilities," memorandum of 20 June 1952, in *AEDC WADC Facilities Study Group*, volume 2.
[48] "Supersonic Wind Tunnel: A Big Job of Heavy Steel Plate Construction," *Engineering News-Record* 155, 7 (18 August 1955): 34-38.
[49] Colonel C.K. Moore, Commander, AEDC, "Costs to Other Military Departments of Conducting Tests at AEDC," memorandum of 14 July 1952, in *AEDC WADC Facilities Study Group*, volume 2.
[50] Air Research and Development Command, "Research and Development: Operation of Facilities of the Arnold Engineering Development Center," ARDC Policy Statement No. 80, 23 April 1953, in *ibid.*
[51] National Advisory Committee for Aeronautics, "Policy for Operation of Unitary Wind Tunnels on Development and Test Problems of Industry," 6 May 1953, in Arnold Engineering Development Center, *Policy on the Use of ARDC Research & Development Test Facilities with Specific Reference to the Arnold Engineering Development Center*, 1949-1953, volume 1.
[52] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 44.
[53] Each of the three facilities is a multi-building complex. In 1951-1958 the configuration the ETF included Buildings 560, 561, 830, 869, 871, 876, 877, 878, and 879 (exclusive of the Ramjet Addition). The Air Force did not substantially complete the GDF until 1959. As of 1961, the configuration of the GDF included Buildings 607, 640, 645, 651, 662, 665, 670, 671, 675, 676, 685, 690, 691, and 692. Similarly, the 1951-1961 configuration of the PWT included Buildings 702, 705, 707 (Tunnel 4T), 708, 710, 711 (Tunnel 16S), 712, 720, 730, 733, 740, 749, 750, 760, 775, 780, 781, 782, 783, 784, 785, 786m 787, 789, 790, and 795 (Tunnel 16T). Science Applications International Corporation (SAIC), *Phase I Historic Building Survey, Arnold Engineering Development Center* (Oak Ridge, Tennessee: Science Applications International Corporation for Air Force Materiel Command, May 1977), *passim.*
[54] SAIC, *Phase I Historic Building Survey, Arnold Engineering Development Center*, 1997, 19; *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 47.
[55] SAIC, *Phase I Historic Building Survey, Arnold Engineering Development Center*, 1997, 16; *History of the Arnold Engineering Development Center 1 January – 30 June 1952*, volume 1, 149; *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 50. PEEWEE and SUPERWEE may have used, or been intended to use, components of the supersonic German Air Research Institute and transonic Yokosuka (German and Japanese) tunnels discussed for AEDC in spring 1952.
[56] "Supersonic Test Center," *Engineering News-Record* 150, 18 (30 April 1953): 30-35; "Details of Tullahoma Test Center," *Aviation Week* 58, 24 (15 June 1953): 36-37.
[57] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 42.
[58] *Ibid, passim.*
[59] Arnold Engineering Development Center, *History of the Arnold Engineering Development Center 1 July – 31 December 1955*, 153, 156-157.
[60] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 64.
[61] *Ibid*, 57.
[62] *Ibid*, 59, 62.
[63] *Ibid*, 61.
[64] *Ibid*, 65.

[65] *Ibid*, 67.
[66] *Ibid*, 68.
[67] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1962*, volume 3, 12.
[68] Office of Public Affairs, Arnold Engineering Development Center, *AEDC: Engine Test Facility (ETF)*, April 1998, 4.
[69] Alton C. Morris, "Rocket test cell...simulates altitude underground," *Air Force Civil Engineer* 2, 2 (May 1961): 22-23.
[70] Office of Public Affairs, Arnold Engineering Development Center, *AEDC: Large Rocket Test Facility J-6*, August 1996.
[71] *Chronology of the Arnold Engineering Development Center 1 July 1970 – 31 December 1977*, unpaginated.
[72] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 109. Building 520 operated as the blockhouse for both Buildings 530 (the J-4 test cell) and 522 (the J-5 test cell).
[73] *AEDC: Large Rocket Test Facility J-6*, 1996.
[74] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 103.
[75] *Ibid*, 62-69.
[76] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1961*, volume 5, 37.
[77] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1962*, volume 5, 22.
[78] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 71-74.
[79] Drawings held in the civil engineering vault, Arnold Air Force Base.
[80] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1964*, volume 5, 10.
[81] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 99, 102, 108, 109.
[82] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1968*, volume 3, 14.
[83] "Space Environment Facility to be Built at Greenbelt," *The Marshall Star* 1, 47 (23 August 1961): 2.
[84] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 99, 126; Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1968*, volume 3, 17.
[85] *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 98-99, 106.
[86] Office of Public Affairs, Arnold Engineering Development Center, *AEDC: Von Karman Gas Dynamics Facility (VKF)*, April 1998.
[87] Office of Public Affairs, Arnold Engineering Development Center, *AEDC: Aeropropulsion Systems Test Facility (ASTF)*, April 1998, 3.
[88] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1973*, volume 2, 38-39.
[89] Headquarters, United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1974*, volume 2, 45.
[90] *Chronology of the Arnold Engineering Development Center 1 July 1970 – 31 December 1977*, unpaginated.
[91] *AEDC: Aeropropulsion Systems Test Facility (ASTF)*, 1998, 2-3, 6; Headquarters, United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1975*, volume 1, 131-132.
[92] Office of Public Affairs, Arnold Engineering Development Center, *AEDC Test Highlights: Space Environment Simulation Capabilities*, 1998, 15-17.
[93] Karen J. Weitze, *Aurora Pulsed Radiation Simulator Historic American Engineering Record No. MD-144* (Plano, Texas: Geo-Marine, Inc., for Army Materiel Command, 1996).
[94] Karen J. Weitze, *Cold War Infrastructure for Air Defense: The Fighter and Command Missions* (San Diego: KEA Environmental, Inc., for Air Combat Command, November 1999), 99.
[95] Irving Stone, "Architect-Engineers Build for Aviation," *Aviation Week* 65, 15 (8 August 1956): 62-69.
[96] Information about DMJM posted at www.dmjm.com. Also, author's files.
[97] Information about Sverdrup & Parcel posted at www.sverdrup.com. Also, author's files.

Chapter 2: Brooks Air Force Base

Historic Missions of the Cold War

Brooks Air Force Base came under the jurisdiction of Air Force Systems Command (AFSC) in November 1961 as an aeromedical research and development (R&D) installation. Brooks, like its nearby San Antonio Air Force bases of Kelly, Randolph, and Lackland, shared a history of operations under Air Training Command. Founded in late 1917, Brooks was one of the older military airfields in the United States. Brooks also achieved very early connections to aeromedicine, a mission common to all four San Antonio bases, with these connections resurfacing in the installation's assignment as host for the United States Air Force Aerospace Medical Center as of October 1959. The Air Force School of Aviation Medicine, moved from Randolph to Brooks as the first operational unit of the center. The Army's School of Aviation Medicine had previously been in place at Brooks between June 1926 and November 1931. The Air Force had planned to resituate its School of Aviation Medicine at Brooks Field during the years immediately following the end of World War II, but delayed in acting until the middle 1950s. At Randolph, a sizeable group of German aeromedical doctors processed through Project Paperclip, had continued work undertaken for the Army Air Forces in Heidelberg in 1945-1946. These men had arrived in San Antonio in 1947-1948 (see Volume I, Part III). (A second group of doctors who had worked in Heidelberg went to the aeromedical laboratory at Wright Field in March 1947.) A few of these individuals moved again from Randolph to Brooks a dozen years later. During the unsettled late 1940s and early 1950s, Brooks hosted the United States Air Force Security Services (USAFSS), while that agency awaited its permanent quarters at Kelly. From mid-1951 through the close of 1958, the 2577th Air Force Reserve Flying Training Center was the primary activity on base. The 1959 timing of the School of Aviation Medicine's shift back to Brooks from Randolph coincided with the rise of the National Aeronautics and Space Administration (NASA), and not surprisingly, the United States Air Force Aerospace Medical Center would support the medical R&D needs of its sister federal agency during the final three decades of the Cold War.

Primary Missions

The primary Cold War missions at Brooks Air Force Base include those of Air Training Command (1959-1961) and AFSC (as of late 1961). These missions focused on:

- service as a reserve training center;
- flight nurse training;
- aeromedical evacuation;
- the United States Air Force School of Aviation Medicine (Aerospace Medical Center);
- medical team tours of duty to Southeast Asia during the Vietnam War;
- development of a prefabricated, modular, air-transportable hospital;
- the Ranch Hand Study (medical analysis of Vietnam veterans exposure to Agent Orange);
- the United States Air Force Occupational and Environmental Health Laboratory (chemical and radiological analyses);
- studies of missile fuel toxicity and development of detection systems for fuel leakage at missile launch sites;
- a crew protection program;
- chemical defense studies, including nerve agent antidotes;
- the United States Air Force Human Resources Laboratory; and,
- the Life Support System Program Office.

Tenant Organization Missions

NASA missions at Brooks concentrated on aerospace medicine and included:

- development of space cabin simulators;
- study of space capsule cabin environments;
- testing of emergency escape systems for space capsules;
- development of biopacks;
- use of monkeys and other animals to test space conditions for astronaut training and preparation;
- pressure suit testing;
- evaluations of pure-oxygen atmospheres;
- decompression studies;
- medical evaluations for pilot-astronauts, Skylab, and space shuttle crews;
- physiological studies supporting space flight;
- participation in developing the manned space station;
- R&D for space food and feeding systems;
- prototyping for space flight hardware;
- nuclear survivability and long-term radiation studies; and,
- lunar material storage.

For a brief period, from April 1949 to August 1953, while awaiting its permanent site at Kelly, the USAFSS also sustained a tenant mission at Brooks, occupying the 1920s School of Aviation Medicine (which had served as a hospital in World War II) and adjacent barracks.

Chronology

Brooks Air Force Base, unlike most Air Force Materiel Command installations, focused almost entirely on facets of a single mission during the Cold War—that of aviation and aerospace medicine. Brooks had been one of a handful of installations in the United States to receive an aeromedical evacuation mission during World War I, with aviation medicine a strong presence during the second half of the 1920s through the School of Aviation Medicine. Brooks Field had hosted an adapted Curtiss JN-4D aircraft, converted as an air ambulance at the installation during its opening year of 1918. Other airfields involved in such proto-aeromedical work using the JN-4D (in individualized adaptations) were McCook Field in Dayton, Ohio (predecessor of today's Wright-Patterson Air Force Base); Carlstrom and Dorr Fields in Arcadia, Florida; Eberts Field in Lonoke, Arkansas; Ellington Field in Houston; Gertsner Field in Lake Charles, Louisiana; Love Field in Dallas; Carruthers Field in Fort Worth; Post Field in Oklahoma (today's Fort Sill); Mather Field in California (today's Mather Air Force Base [closed]); Rich Field in Waco, Texas; Rockwell Field in San Diego, California (North Field); Scott Field in Illinois (today's Scott Air Force Base); Souther Field in Americus, Georgia; and, Taylor Field in Montgomery, Alabama. In San Antonio, personnel at Kelly Field also improvised an air ambulance in 1918, using a Curtiss R4 aircraft. The Air Service Engineering Division subsumed beneath the Airplane Engineering Division at McCook Field had initiated systematic exploration of aeromedical evacuation, although work toward an air ambulance happened simultaneously and independently at several airfields—with that of Gertsner possibly the very earliest. Within the Air Corps, the Director of Military Aeronautics had issued a memorandum in late July 1918 to all airfields to adapt aircraft as air ambulances. The Air Corps had noted that photographs and drawings of the air ambulance at Gertsner would follow. The concentration of air ambulances in Texas in 1918 is particularly noteworthy. The revolution in Mexico had stimulated border raids and skirmishes by Francesco (Pancho) Villa and his band of guerrillas. President Wilson

had sent General Pershing to the area, but withdrew him when the United States entered World War I. Generally, these first air ambulances evacuated downed pilots at high-risk gunnery ranges, but along the remote Texas-Mexico border the adapted aircraft were also in active service test into the early 1920s as a consequence of Villa's raids.[1]

In addition to the Air Service Engineering Division at McCook Field, the Army established two aeromedical facilities on Long Island in 1918: a Medical Research Laboratory and a School for Flight Surgeons at Hazelhurst Field. The Hazelhurst facility came about after American review of a study that had concluded there was a strong need for aviation medicine. In early World War I, the British calculated that only 10% of pilot fatalities were due to enemy action or aircraft failure. Thirty percent happened as a result of pilot recklessness, and a full 60% occurred "because they [the pilots] were physically unfit to fly in the first place." To augment interpretations of pilots' special medical needs, the Army included a decompression chamber in the research laboratory at Hazelhurst. Army doctors used the facility to research human tolerance to lowered oxygen tension and to assist in training flight surgeons.[2] Simultaneously, efforts went forward after World War I in advancing Army aeromedical evacuation. The Air Service Engineering Division at McCook was working with Kelly depot personnel by 1920 to convert the JN-4 to a standard air ambulance—already having had the depot adapt the R4. Kelly continued such efforts into the early 1920s, with the air ambulances assigned where needed. The depot modified other aircraft for possible air ambulances, such as the DeHavilland DH-4 in 1920 and the Fokker Y1C15 in 1931. San Antonio hosted the joint annual meeting of the Medical Service Association and the Military Surgeons Association in 1924,[3] and as of 1926 the Army's School of Aviation Medicine moved from New York to Brooks Field. (A location at Mitchel Field, also on Long Island, had followed that at Hazelhurst as of late 1919, with a name change from the Medical Research Laboratory to the School of Aviation Medicine in 1922.) The Army selected the Brooks site to place the school near the aviation cadet training centers in San Antonio. The School of Aviation Medicine functioned as an educational institution not only for Army pilots, but also for those of the Navy (until that service established its own school of aviation medicine in Pensacola, Florida, in 1939) and for foreign medical officers (as of 1923).[4] By 1930, the aeromedical missions at Wright, Kelly, and Brooks Fields were thoroughly linked together, albeit with divergent roles. While the early aeromedical mission had never been the only activity at Brooks Field, between 1918 and 1932 progressive aviation medicine had helped to define the installation. Doctors at the School of Aviation Medicine at Brooks administered physical exams for Army flight personnel and trained flight surgeons.[5] At the close of 1931, the School of Aviation Medicine moved from Brooks to neighboring Randolph, while an aeromedical mission was in hiatus at Brooks between 1932 and 1959. At Randolph, a single building housed the main activities of the School of Aviation Medicine until 1941-1942, when the base added a research institute. The former School of Aviation Medicine Brooks became a hospital complex for its installation, with barracks added nearby during World War II. As of the middle 1930s, an aeromedical laboratory was also emerging at Wright Field in Ohio.

Brooks Air Force Base was first known as Gosport Field and Kelly Field No. 5 while under construction during 1917-1918 (simultaneously with Kelly, and planned as an auxiliary field for that installation). Opening as Brooks Field in early 1918, the airfield functioned chiefly as a flying school and flight training location through World War II.[6] Twelve hangars lined the airfield's semicircular flightline: eight wooden structures designed by draftsmen in the office of Detroit architect Albert Kahn and four standard steel hangars designed for the War Department by Fisher & Christy. Albert Kahn's firm handled the original site plan and individual buildings for the installation in 1917-1918. Brooks hosted the Air Corps Balloon and Airship School during 1919-1922, which brought its signature dirigible hangar to the base (Hangar 9). (The dirigible hangar would also house the School of Aviation Medicine from 1926 into mid-1927, while permanent facilities for that mission were under construction.[7]) Brooks operated the Air Corps Primary Flying School between 1922 and late

1931. Thereafter, the installation served as a center for observation squadrons until it became an Air Corps Advanced Flying School (the Army Air Forces Pilot Training School) as of December 1940. The mission of advanced pilot training continued into 1945.[8] Air Corps / Army Air Forces pilot training programs were interwoven in San Antonio between Kelly, Randolph, and Brooks Fields, a situation very similar to that for the aeromedical missions over time. The Air Corps ran its training as "primary" and "advanced." During the 1920s, Brooks Field handled primary training, while personnel at Kelly ran the advanced training program. As of the establishment of Randolph Field in 1931, basic cadet and primary training occurred there, with advanced training at Kelly. In autumn 1939, Brooks became a subpost of Kelly to absorb the increased student load in advanced pilot training. The advanced pilot training mission shifted entirely to Brooks by 1941. As World War II came to a close, Brooks became a subpost of Randolph in April 1945. The Army Air Forces declared Brooks surplus as a training installation by October.

During the first years of the Cold War, Brooks Field sustained little activity. The base fell under the jurisdiction of sequential commands, but without a well-defined mission. Brooks rotated from Strategic Air Command (SAC) to Tactical Air Command (TAC) in 1946, and to Air Defense Command (ADC) in 1947. In June 1948, Brooks Field became Brooks Air Force Base.[9] As the Cold War opened, the installation featured three runways—each of about 5,000 feet in length—with nearly all buildings and structures of woodframe, semipermanent construction. As of 1957, ADC had neither extended nor replaced the runways at Brooks, and only four buildings of permanent construction were interspersed among the structures of the flightline and cantonment. Most buildings were World War II woodframe temporaries. The more substantial infrastructure was from World War I. One of the permanent buildings was the mid-1920s stucco-on-frame School of Aviation Medicine (Building 538), while two were airmen dormitories of post-World War II construction. Seven modern buildings for a new School of Aviation Medicine were under construction in the northwestern corner of the installation, removed from the main base (Plate 18). As the School of Aviation Medicine became fully operational and was subsumed within the United States Air Force Aerospace Medical Center, all flight activity ceased at Brooks. The Air Force removed the runways from use in late June 1960.[10] In 1962, a flightline fire led to the demolition of all but two of the World War I hangars (one wooden and one steel hangar remaining).[11]

A mix of activities, predominantly housed in infrastructure of 1918-1943, characterized the period of 1947 to 1959 at Brooks. Attempts to bring the aeromedical mission back to the base were complicated and suffered from multiple starts, stops, and interruptions. The Army Air Forces sought to reestablish a large group of significant German doctors and their associates at an American installation as soon as possible post-war. Led by Dr. Hubertus Strughold, these men and women numbered about 40 aeromedical professionals. Between autumn 1945 and early 1947, the Army Air Forces had operated a formal Aeromedical Center in Heidelberg where the Germans continued their work of the late 1930s and early 1940s. The Aeromedical Center in Heidelberg, literally a redesignation of the Kaiser Wilhelm Institute, also had an affiliate group at the Helmholtz Institute in Berlin. The operations in Heidelberg and Berlin led directly to a dispute between the United States and the Soviet Union which forced the closure of the Army Air Forces sponsorship of German aeromedical R&D in Germany. (The Soviet government argued that the Aeromedical Center in Heidelberg and the Helmholtz Institute in Berlin violated Public Law No. 25.) The Army Air Forces began studies toward a state-of-the-art aeromedical center to accommodate a transfer of the Heidelberg-Helmholtz group to the United States as of August 1946. The first men and women arrived in the United States in 1947 under Project Paperclip. A number of these individuals went to Wright Field to work in the aeromedical laboratory there, but about 26 aeromedical professionals went with Dr. Strughold to the existing School of Aviation Medicine at Randolph (Plate 19). While the school at Randolph had never achieved the large-scale research compound it desired, ambitious aeromedical R&D had been underway there as of 1934. Work had included psychological testing;

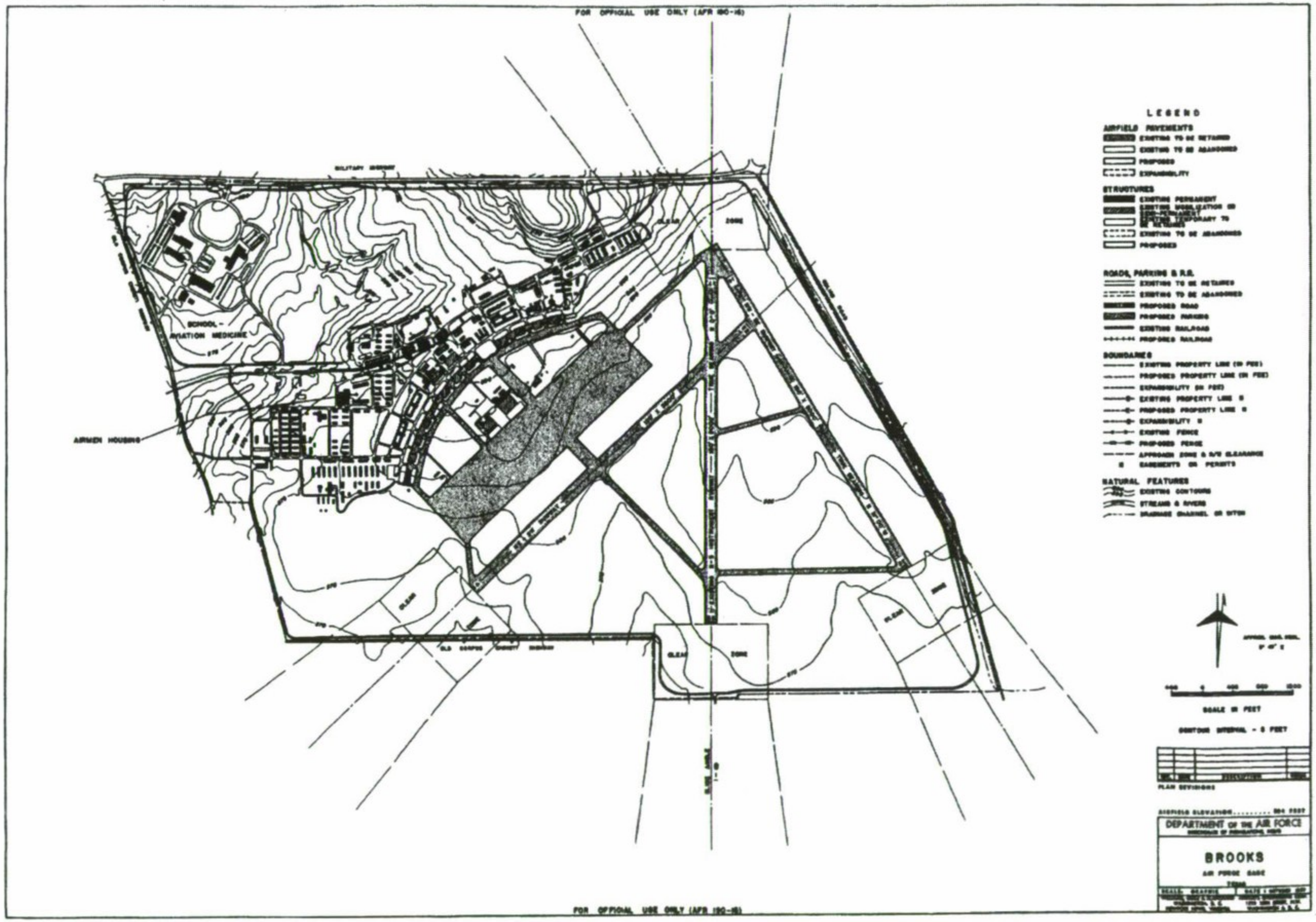

Plate 18: Directorate of Installations, Headquarters United States Air Force. Master Plan for Brooks Air Force Base, October 1957. The Aerospace Medical Center is located in the upper left corner. Collection of K.J. Weitze.

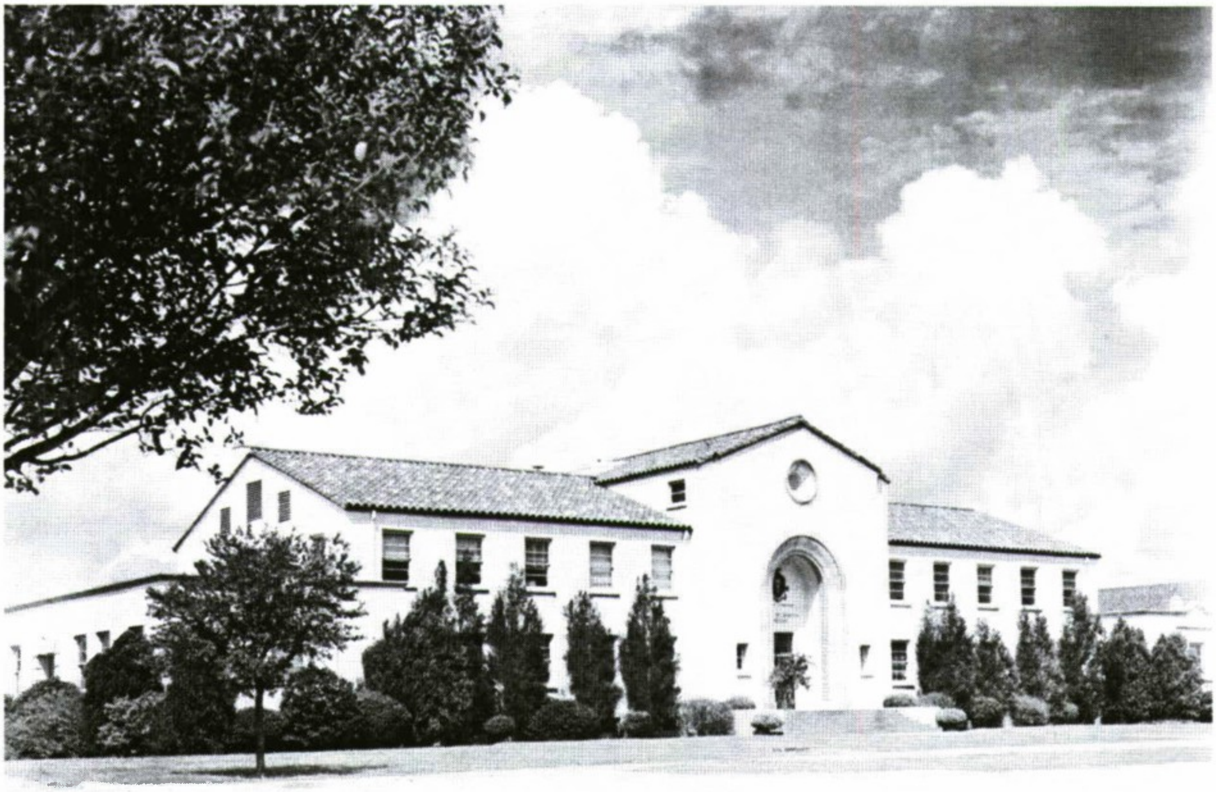

Plate 19: Research Building at the School of Aviation Medicine, Randolph Field, ca.1942. In *Annual History 1948-1949 School of Aviation Medicine*, volume 8.

development of aviation goggles; studies of vision in aging pilots, night vision, cockpit lighting, and color blindness; and, standardization of a kit for flight surgeons. Lack of a pressure chamber, however, particularly hampered the institution until the addition of the research building in early World War II. More sophisticated studies went forward under Major Harry G. Armstrong, appointed as director of research for the School of Aviation Medicine in 1942. At the war's end, personnel at the School of Aviation Medicine at Randolph had completed more than 500 aeromedical research projects. Research, in fact, dominated aeromedical activities at the base, with related missions dispersed across the United States (see below). New R&D included studies on the influence of aircraft noise and gunfire on hearing, the presence of carbon monoxide in cockpits, and decompression sickness.[12] In the late 1940s, the Paperclippers at Randolph and Wright Fields continued very important studies and experiments previously underway in Germany—especially true of the professionals in San Antonio. A team of medical documents translators, as well as a outstanding technical library, also moved to Randolph. The men and women at Randolph almost immediately began publishing technical articles in the American *Journal of Aviation Medicine*, and the Army Air Forces (Air Force) undertook a major compilation of existing articles by this group and other doctors across Germany as *German Aviation Medicine World War II*. Many of the individuals at Randolph had long and distinguished careers in aeromedicine (see Volume I, Part III).

The process of determining the location and physical character of a new Army Air Forces / Air Force aeromedical center moved very slowly during late 1946 through 1947. Under the direction of Brigadier General Malcolm C. Grow, the Air Surgeon at Headquarters Army Air Forces, the Army considered at least 15 sites as possible hosts for the center. Brooks Field was in this mix, but does not

appear to have been a strong preference. By late 1947, the School of Aviation Medicine at Randolph recommended that the United States Naval Hospital in Houston become the property of the Air Force for its aeromedical center (Plate 20).[13] This facility sat near Ellington Field—long a military airfield associated with aviation medicine and home of multiple experimental air ambulances. The Navy's hospital was new, designed as a multistory, multiwing complex. It had opened in late 1946 and included over 100 acres at its site. A building program for large, state-of-the-art Naval hospitals continued into the early 1950s and typically featured pavilion-plan, high-rise structures with a central core and splayed lateral wings. The Bureau of Yards and Docks, the equivalent of the Army Corps of Engineers and the civil engineering function within Air Materiel Command, was internationally known for its progressive engineering under Arsham Amirikian as of very early in the 1940s. Not surprisingly, the Bureau of Yards and Docks hired some of the best architects and engineers for its hospital program of these years.[14] The Navy compound in Houston was immediately adjacent to the Texas Medical Center, a large medical joint establishment of the University of Texas and Baylor University. The Texas Medical Center abutted Rice Institute (today, Rice University) and the Olmstedian Hermann Park. (Today the medical schools of these universities sustain a continued presence at the site, as does the world-renowned H.D. Anderson Cancer Hospital.) The Texas Medical Center and Rice Institute are the most likely immediate sources of a collegiate concept for the later aeromedical center at Brooks. The notion of a collegiate plan for an Air Force aeromedical center, however, derives from a national fascination with this idea during the 1945-1955 period, a fascination especially strong for the design of modern science laboratories (see Volume I, Part III). The Air Force approach to an aeromedical complex diverged from that of the Navy for its hospital research complexes and focused very strongly on a campus of laboratories. Only one detail, the half-circle formal drive approaching the Brooks compound, appears to be taken from site planning for the Navy's hospital program in Houston (and elsewhere).

Plate 20: United States Naval Hospital, Houston, ca.1946. In *A Proposed United States Air Force Aeromedical Center August 1946 – August 1949.*

Harry Armstrong submitted a detailed packet of materials to the Air Surgeon at Headquarters Air Force on 29 December 1947 to make his case about the United States Naval Hospital in Houston. Promoted to Colonel, Armstrong was commandant of the School of Aviation by this date. Of note, Colonel Armstrong did not choose the United States Naval School of Aviation Medicine in Pensacola or the Naval Air Crew Equipment Laboratory in Philadelphia as his model for the proposed Air Force school, probably indicating that the Navy compounds were at a parallel level of development with the Air Force as of the late 1940s. (The Navy's School of Aviation Medicine dated to 1939, while the Crew Equipment Laboratory went in place in 1942. The Naval School of Aviation Medicine would include low-pressure chambers, low-level alpha-radiation and electrophysiological laboratories, slow-rotation room, and human-disorientation device by the late 1950s. The Crew Equipment Laboratory conducted basic research in aviation medicine related to equipment.[15]) In his cover letter, Colonel Armstrong noted that the sixty buildings then occupied by the School of Aviation Medicine at Randolph included only six that were the property of the school. The remainder were all World War II temporaries, and belonged to Randolph Field. He reminded the Air Surgeon that plans for a much-needed aeromedical center for the Army Air Corps had predated the war, and that the war itself had been the primary cause of sustained delays for such a center. To alleviate conditions at Randolph, the Air Surgeon had decentralized aeromedical activities previously all at Randolph. Moved medical schools had included the Air Evacuation School (shifted to Bowman Field in Kentucky), Medical Field Tactical School (to Orlando Army Air Base in Florida), and Medical Field Service School (to Warner Robins Field in Georgia). The Army had also transferred a number of other activities to the aeromedical laboratory at Wright Field. Armstrong estimated the cost of a new aeromedical center at $30,000,000. Colonel Armstrong's proposal for an adaptation of the Naval Hospital floundered, however. During 1947 and 1948, Air Force action toward an aeromedical center focused on the bringing the Heidelberg-Helmholtz aeromedical professionals to the United States under Paperclip, and on setting up shipped equipment and a technical library. Dr. Strughold and his colleagues held symposia at Randolph for the Air Force, and at the end of 1948 Dr. Strughold introduced the topic of space flight from an aeromedical perspective. The process of approving new aeromedical facilities in this period may also have suffered from a basic dilemma within the Air Force: the Army Air Forces School of Aviation Medicine at Randolph was subsumed under the Air University at Maxwell Field in Montgomery, Alabama, at the end of World War II. Air Training Command was the host command at Randolph, while the aeromedical laboratory at Wright Field was within Air Materiel Command. The three command structures within the Army Air Forces / Air Force suggests that Headquarters Air Force not only had to authorize where and how an aeromedical center would exist, but also under what command.[16]

Movement toward an Air Force aeromedical center picked up again in 1949. In that year, the School of Aviation Medicine at Randolph established a Department of Space Flight headed by Dr. Strughold and staffed by Paperclippers Fritz and Heinz Haber (brothers) and Konrad Buttner. Harry Armstrong, still commandant of the school, followed Malcolm Grow as Surgeon General of the Air Force. Before leaving Randolph for Washington, D.C., he set up an Aeromedical Planning Board at mid-year[17] that included representatives from the existing School of Aviation Medicine, the Air University, and the Office of the Surgeon General. The board again looked at multiple sites across the United States, and by autumn leaned toward adaptation of the Naval Hospital in Corona, California. The board's decision implied that General Armstrong still leaned toward the Naval research hospital as his preferred model. Discussions also addressed a high-cost alternative on a completely new site. The challenge of space flight was uppermost on many minds, and arguments went back and forth. With entry into the Korean War, planning moved forward again after some months of hiatus. As of July 1950, the Air Force Chief of Staff recommended that the aeromedical center be in San Antonio, with proximity to existing facilities at Randolph. Surgeon General Armstrong was a significant force in getting the project back on track, and probably also the impetus for a site choice in Texas. However by 1949, site availability at Brooks had become somewhat

compromised. As of mid-April, the USAFSS had moved to the base and occupied one of the installations' very few permanent structures—the 1920s School of Aviation Medicine. The USAFSS also took over World War II barracks near the earlier school for its needs. As an intelligence agency, the USAFSS derived from a preexisting Army agency in Washington, D.C.-Virginia. The USAFSS achieved an independent role due directly to the founding of the Air Force in mid-1947 (as an outgrowth of the increasingly autonomous Army Air Forces), and like the School of Aviation Medicine, needed new facilities and an assigned location. While the Air Force decided to build the permanent USAFSS compound at Kelly in San Antonio (see Volume II, Chapter 7), the agency moved personnel and equipment to a temporary station across town at Brooks during construction. The complications of having the aeromedical mission continue at Randolph, coupled with the intelligence mission temporarily in place at Brooks, once again stymied the planning process for the new Air Force aeromedical center.

Nonetheless by early 1951, Air Installations (civil engineering) at Headquarters Air Force was working with Air Materiel Command at Wright-Patterson Air Force Base in overseeing a contract for the design of the needed center. At the outset of February, the Air Force plan for an aeromedical center called for five main buildings, support structures, and housing: a school of aviation medicine, aeromedical institute, clinic, research institute, library, bachelor officers' quarters, barracks, and family quarters. Major General Armstrong projected the cost for these facilities at $20,000,000, with another $10,000,000 needed for basic infrastructure and support buildings. Armstrong's cost profile of 1951 remained consistent with his vision of 1947. The Office of the Secretary of the Air Force had interpreted the high costs as questionable in its review of 1950, and had suggested only an $800,000 initial appropriation for Fiscal Year (FY) 1951.[18] Air Materiel Command hired Ellerbe & Company of Minneapolis-St. Paul for the job of designing the aeromedical center in March 1951. The command instructed Ellerbe & Company to use Brooks as the "typical site," which suggests that the San Antonio base was still not firm as the final selection for the aeromedical center's permanent location. Brooks was essentially a collection of woodframe buildings, with little in place to support the new school. Ellerbe & Company worked on the master plan for the center and drawings for individual buildings during 1951-1953, while Air Materiel Command contracted separately for a new master plan for the base. The firm completed their initial set of drawings for the aeromedical center in July 1952 (see Volume I, Part III). While Ellerbe & Company worked on the project, the Air Staff divided it into three phases. After more changes, the Bureau of the Budget cut funding for a first phase of $10,000,000 to $8,000,000. Congress passed the lower figure in July 1952, for work in FY1953.[19]

Ellerbe & Company's efforts toward the center complemented the firm's simultaneous designs for standardized hospitals across the Air Force. Franklin Ellerbe had founded Ellerbe & Company (today, Ellerbe Becket, after an acquisition of Welton Becket in 1987) in 1909.[20] The first Mayo Clinic group practice building of 1912-1914 had been among the firm's earliest projects (as Ellerbe & Round). The firm had designed the Mayo Clinic facilities by working closely with Dr. Henry Plummer at the clinic. The Mayo Clinic in Rochester, Minnesota, was the first hospital setting to include clinical departments, laboratories, workshops, and other services under a single roof, with exam rooms linked via a proto-intercom system to a main area.[21] As of 1921, Thomas Ellerbe took over the practice from his father. He continued to establish a major reputation for the firm in the design of hospitals and health-care facilities. Examples of hospital innovation as of 1922 included designing rooms with private baths. During the 1940s, Ellerbe & Company developed five new hospital plans in cross, radial, cloverleaf, Y, and five-sided configurations. During World War II, the firm also experimented with innovative materials. Ellerbe & Company designed the Northwest Airlines hangars at the St. Paul airport in laminated pine, with arch-trusses 170 feet across. These trusses were the largest up to that time using laminated beams.[22] Of note, only the 177-foot laminated arches designed by Anton Tedesko (Roberts & Schaefer) several years later for the Army Air Forces'

modification center at Vandalia, Ohio (near Wright Field), were longer—and both commissions had been for Air Materiel Command (see Volume I, Part II and Volume II, Chapter 14). Ellerbe & Company had also finished a large, multistory addition to the Mayo Clinic immediately before contracting to Air Materiel Command for the Air Force aeromedical center.[23]

Progress toward the aeromedical center at Brooks continued to be very slow even after the hiring of the experienced firm of Ellerbe & Company and initial Congressional funding. Draftsmen at Ellerbe & Company worked closely with engineers at Air Materiel Command at Wright-Patterson. They made back-and-forth revisions to drawings for the cluster of buildings that would comprise the center. Ellerbe & Company's aeromedical center included a school of aviation medicine, research institute, rehabilitation clinic, and administration and clinic building. The center also featured altitude, motion, and "adaptable" laboratories, and their accompanying shops. Ellerbe & Company also designed a power plant for the center and handled the project's utilities. Air Force project files indicate that the firm completed drawings for the aeromedical center in September 1953. Nine large buildings comprised the total aeromedical complex (see Volume I, Part III). While the group differed from the compound proposed by Surgeon General Armstrong in 1949, it still vibrantly reflected his ideas. As of November 1951, site selection for the center had solidified as Brooks Air Force Base in San Antonio. During the 1949-1951 years also, the Navy went forward with its Naval Air Development Center in Johnsville, Pennsylvania. This R&D center dated to August 1947 as the Naval Air Development Station and had initially featured three laboratories: aircraft electronics, guided missiles, and aviation armament. The cluster reflected the national trend toward grouped science laboratories planned as a collegiate enclave, but was not a direct model for an aeromedical laboratory compound until the addition of a human centrifuge laboratory for aviation medicine during 1949-1951. The centrifuge at the Naval Air Development Center was a major facility for aeromedical research, one that played an important role in high-altitude and space programs for the Air Force (in the X-15 and Dyna-Soar programs) as well as NASA (for Project Mercury) in the years before 1960.[24] Articulation of the Naval Air Development Center as a four-laboratory campus may have influenced the design developed by Ellerbe & Company in 1951-1953, or both designs may have drawn upon the phenomenon occurring widely across the nation.

Yet even with the design for an aeromedical center at Brooks finished and the site no longer in dispute, more delays continued to complicate the project. Simultaneous with its work on the center for Air Materiel Command, Ellerbe & Company was in a dispute with the Army Corps of Engineers and Headquarters Air Force on its concurrent design for a standard Air Force hospital (see Volume I, Part III). The central issue of 1953 was an unpaid cost overrun. By mid-1955, the Air Force, Army, and Navy were additionally calling for a redesign of the standard hospital for the tri-services. Another concern focused on the need to update the standard Air Force hospital of Ellerbe & Company—a design which dated to about 1948. The late 1940s drawings had been geared toward ideal use, and apparently were not easily adapted to specific military situations. The office of the Assistant Chief of Staff, Installations, at Headquarters Air Force (the forerunner of the Directorate of Civil Engineering) summarized the situation point by point.

> (1) The standard plans as they now exist were based on 1948 obsolete hospital standards.
> (2) Certain functional areas were deficient and excessive in others.
> (3) Plan arrangement was not quite suitable for use by any one of the three services.
> (4) The standard plans are based on a hypothetical situation without regard to mission, workload, terrain, climate or site.[25]

The office of the Assistant Chief of Staff, Installations, noted that the Air Force had hired Faulkner, Kingsbury & Stenhouse "to prepare new [hospital] designs based on the revised criteria."[26]

No actual construction went forward for the Air Force aeromedical center during the long period of 1946 to 1956. In July 1951, the 2577th Air Force Reserves Training Center opened at Brooks and became the installation's base operating unit in January 1954. During 1949-1955, Brooks also hosted a series of mobile radar squadrons. As of 1950, WAF (Women in the Air Force) squadrons served at Brooks, with the first squadrons the 2213th, 2250th, and 6922nd. In mid-1952, the Air Force assigned the 8707th Medical Group to the base to support the 8707th United States Air Force Hospital. The mission of 8707th Medical Group focused on pilot flight training, with its numbered hospital, airbase group, field maintenance, installations squadron, maintenance and support, and WAF squadron indicative of the true Cold War rebuilding of the base. Medical missions foreshadowing the arrival of the Aerospace Medical Center in 1959 included those of a numbered dispensary unit in 1954 and an aeromedical transport group in 1956.[27] The aeromedical missions at Randolph, in addition to the installation's acquisition of Dr. Strughold's team for the School of Aviation Medicine, had also expanded through the absorption of the Army Air Forces School of Air Evacuation as of 1945 (assigned back to Randolph from Bowman Field in Louisville).[28] The Schools of Aviation Medicine and Air Evacuation continued at Randolph from the middle 1940s to 1959. Thereafter, they both moved to Brooks. The aeromedical evacuation courses at Bowman, Randolph, and Brooks offered a specialized type of flight nurse training to care for the sick and wounded during airlift to military hospitals. The first training of flight nurses at Brooks dated to 1954, when nurses participated in the airlift of French soldiers out of a rapidly destabilizing Vietnam. Aircraft conversion to air ambulances continued steadily at Kelly from the late 1940s forward, with Brooks serving as a center of aeromedical evacuation from the middle 1950s through the end of the Vietnam War. At the war's formal conclusion in 1975, flight nurses from Brooks helped bring American prisoners of war home aboard aeromedical aircraft.[29]

Momentum toward a state-of-the-art aeromedical center picked up again in 1956. The Air Force commissioned the first six buildings for the center at Brooks from the Austin firm of Texas Architect-Engineer Association. The actual design process for these buildings remains obscured. The drawings include the Texas Architect-Engineer Association in all title blocks, yet the printed descriptive names for each building either exactly match those of Ellerbe & Company in their completed drawings of late 1953, or match in terms of detailed function. The question remains, then, whether the Flight Medicine Laboratory (Administration and Clinic Building) (Building 100), Research Institute (Building 125), Research Laboratory Shops (Building 130), Altitude Laboratory (Building 160), Power Plant (Building 165), and Academic Building (School of Aviation Medicine) (Building 180) are the work of the Texas Architect-Engineer Association or of Ellerbe & Company (see Volume 1, Part III). The practice of purchasing drawings from an architectural-engineering firm, with their subsequent redistribution through a regional Army Corps of Engineers office, was thoroughly commonplace for this period. A local architectural-engineering firm typically inserted its name in the title blocks and left the formal designations of the buildings (as well as the drawing numbers) as originally received. When this occurred, the local firm's contribution consisted of site adaptation and any required modifications. The tri-services had also interpreted the standard military hospital by Ellerbe & Company of the late 1940s as obsolete, with the request that the replacement designs of Faulkner, Kingsbury & Stenhouse be of multistory permanent type.[30] The Ellerbe & Company hospital had been one-story. This design had derived from controversies concentrated on economizing during World War II.[31] The continuance of a one- and two-story emphasis for an aeromedical complex as late as 1956 was another peculiarity of the situation at Brooks, and suggests that these six buildings are predominantly the work of Ellerbe & Company from 1951-1953. In an article of 1962 in *The Military Engineer*, the Southwestern Division of the Corps of Engineers and the Air Force regional engineer for the Southwest credited Ellerbe & Company and the Texas Architect-Engineer Association as jointly responsible for these structures.[32]

Three architectural firms comprised the Texas Architect-Engineer Association in 1956: Charles H. Page & Son; Thomas, Jameson & Merrill; and, Weidner & Walther. Charles H. Page may be related to the Page family of architects working in central Texas as of about 1907. Harvey L. Page (1859-1934) designed railroad depots, county courthouses, and multiple civic buildings in San Antonio and Corpus Christi.[33] Later, during the middle 1930s, the Page Brothers designed the Moderne Travis County courthouse in Austin.[34] While historians have researched very little about the work of the three regional firms that comprised Texas Architect-Engineer Association, their alliance in the middle-1950s reflected a progressive trend within the American architectural profession as of about 1940. Such associations were most often found between architects and engineers practicing in the International Style and with offices emulating a Bauhaus environment (see Volume I, Parts II and III). Of some note perhaps, the Air Force (and Air Materiel Command in particular) hired this type of firm on more than one occasion during the 1941-1960 period. A good early example was the Air Depot Architect Engineers of New York—a 1941 affiliation between Alfred Easton Poor; Gibbs & Hill; and, Fred N. Severud. The most high-profile example was that of The Architects Collaborative, formed in 1945 by ex-Bauhaus German architect Walter Gropius and others through Harvard University in Boston. Even Weidlinger Associates, Inc. of New York, (WAI), a contemporary firm dating back to Weidlinger Associates of about 1950, was originally a true modernist partnership between some of the most distinguished international engineers of mid-century (see Volume I, Parts II and III).

Beginning in December 1956, the Texas Architect-Engineer Association presented drawings for the renewed aeromedical center at Brooks. The master plan for the center showed a fully planned complex overlaid upon a preexisting jumble of unpaved roads, a ball park and a small arms firing range (both to be removed), and the concrete-pad remnants from previous structures no longer on site (see Volume I, Plate 61). A divided median accented the formal entry off the Military Highway, with a centered security gate house serving as a checkpoint before turning onto a circular drive (the single detail reminiscent of the Naval Hospital in Houston of the previous decade). The aeromedical center included five main buildings within a rectangular grid of open courtyards and parking areas. To the rear, outside the grid, were a power plant, cooling tower, and switching station situated along the installation's perimeter road paralleling the Old Corpus Christi Highway. The utilities system was especially important in order to sustain "uninterrupted environmental conditions for long term experiments." The power plant included a supervisory data center to monitor heating and air-conditioning throughout the aeromedical complex. A large control panel tracked environmental conditions and warned of any malfunctions. In addition, each of the primary research buildings included emergency power supplies as backup to prevent any disruption of operations. Heating, ventilation, and air-conditioning was also segregated for clean and contaminated areas. As a final precaution to sustain a constant power source throughout the aeromedical center, a system of underground walk-through tunnels connected the power plant and the individual buildings.[35] In contrast, the openness of the aboveground master plan was striking. The amount of parking was also notable. Architects had included seven parking lots spread throughout the complex, designed as appropriate for a university setting or for that of multiple laboratories. The larger lots featured turf-landscaped dividers and bracketing beds that created the effect of three to four small lots within each, rather than unbroken expanses of pavement. The courtyards were uncluttered, with a diagonal walkway across the courtyard between the Altitude and Academic Buildings. The plan implied that all courtyards were simple turf. A low-walled terrace at the rear of the Academic Building, paved with flagged stone, featured a centered fountain with tiled surround and corner ground cover. The area encircled by the entrance drive was also fully open—with no buildings, parking, or walkways to break a visitor's first impression of the complex.[36]

A visitor circled to the main complex after passing the security check point, either turning into the cluster of two laboratories, research institute, and laboratory shops characterizing the west and

southeast areas, or, parking in one of the lots bracketing the Academic Building (the School of Aviation Medicine) at the northeast. The school was the only irregularly shaped building within the group. Each of the five buildings, with the exception of the Research Institute, featured a low, one-to-two-story profile, with all details accenting the horizontal character of the complex. A very narrow, running bond articulated the exterior brick facing the concrete-block structures. Stone copings along the first- and second-story roof lines and a concrete horizontal finishing detail accenting the upper façade further emphasized the buildings' horizontality. Granite steps and stone door surrounds were the only other decorative details, with fenestration and doorways minimized. Most facades featured very few, or no, windows. When fenestration did delineate a façade, the windows were horizontally banded single-pane, plate glass with aluminum framing. The architects treated metal louvered vents in the same manner. In three instances, buildings featured a penthouse sheathed in aluminum insulated paneling, while aluminum paneling entirely sheathed the one-story, windowless Altitude Laboratory. A projecting, rectangular expanse of dark blue porcelain enamel-finished paneling accented its entrance. The overall composition for the five main buildings of the aeromedical center emphasized industrial science, with a careful design interplay between brickwork, aluminum, and isolated entries highlighted through stone surrounds or porcelain enamel surfacing (Plate 21). *The Military Engineer* described the Air Force center as designed in a "contemporary style of architecture...for maximum flexibility to accommodate the changing technological progress in the field of aerospace medicine."[37]

The Academic Building, in its role as the new Air Force School of Aviation, focused dramatically inwards and set the tone for the group as a whole. A large glazed façade showcased the stairwell and offered the only vertical emphasis for the composite one- and two-story structure. The banded windows articulated administrative space, with all other facades blind to activities outdoors. The first floor included three large classrooms for 120, 150, and 200 people, respectively, as well as a sloping assembly hall for 433 people, smaller classrooms, laboratories, offices, and a snack bar-lounge facing onto the rear terrace. The second floor featured a large classroom, a demonstration amphitheater, two large areas for general physicals, and multiple small rooms.[38] Total classrooms numbered 16, and seated 735 students. Closed circuit television broadcast clinical procedures to the assembly hall and some of the classrooms—a true innovation in the late 1950s.[39] The Flight Medicine Laboratory, a one-story structure flanking the immediate west of the circular entrance drive, showcased all of the design features found in the Academic Building, as did the Research Institute, Research Laboratory Shops, and Altitude Laboratory. This laboratory included small examination rooms, specialized test facilities, and a centralized records repository.[40] The paired Research Institute and Research Laboratory Shops were immediately behind the Flight Medicine Laboratory. The Research Institute broke the low pattern of the medical complex with the four-story-and-penthouse profile of its main wing, but strongly sustained the inward-looking character of each building within the group. Again, banded fenestration accented only the public façade (toward the circular drive), and was virtually absent above the first floor. The upper stories also projected out beyond the first floor on the building's public face—further emphasizing the self-contained research atmosphere of the complex. The Research Laboratory Shops sited behind the institute returned to the aeromedical center's low profile. Its ground story again featured the very narrow horizontal brick veneer, minimal fenestration, and selected stone entrance surrounds. The Research Laboratory Shops functioned primarily as a general purpose workshop. The building included instrument storage and shop space; printing and film processing facilities; a studio; and, a large carpenter shop.[41]

The interior layout of the Research Institute was particularly complex. The basement featured multiple laboratories, animal and human exam rooms, a cluster of sound booths with control rooms, anechoic and reverberation chambers, and mechanical equipment. Center personnel were able to use the anechoic chamber to produce a condition "approximating zero decibels of sound...for the study of

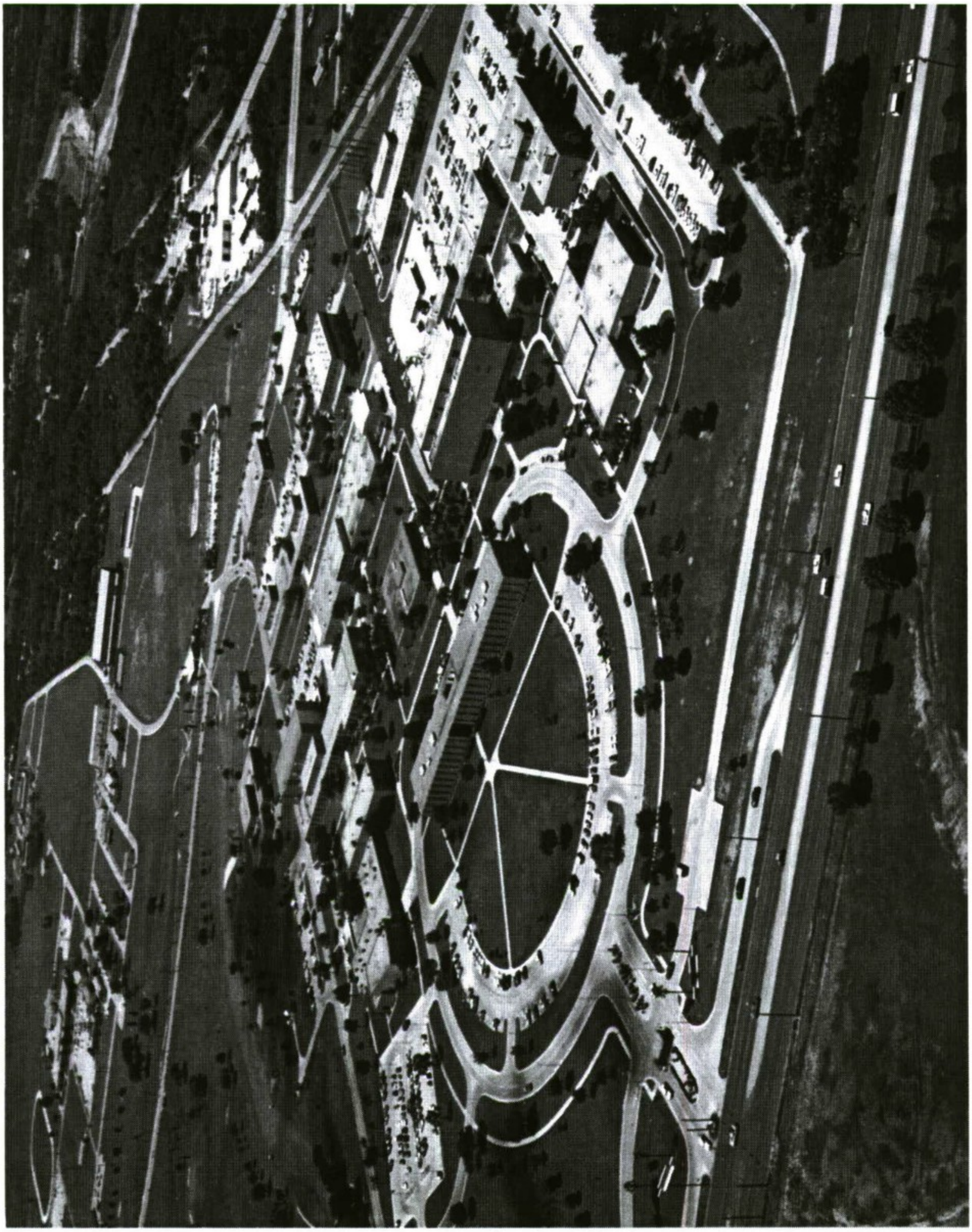

Plate 21: Ellerbe & Company, Texas Architect-Engineer Associates, and Smith, Hinchman & Grylls. United States Air Force School of Aerospace Medicine, ca.1965. Courtesy of the History Office, Brooks Air Force Base.

psychological and physiological reactions of humans and animals under conditions of absolute silence." The room was a particular feat:

> This condition is attained through suspension of a cage-like structure within a concrete-walled room for elimination of outside sound vibrations. The cage is walled with acoustical panels ranging to 3 feet in thickness and arranged in overlapping geometric patterns to absorb sound. The noise level in this room is so low that a person sitting perfectly still can hear his own heart beat.[42]

Both the anechoic and reverberation chambers were part of the audiology laboratory for the center. The institute also contained one- and two-man space cabin simulators. The first floor of the institute housed the major administrative space; large and small animal cages; and, an animal operating room. The second floor of the Research Institute housed uniformly-sized research project offices and laboratories, with a classified reading room and documents security vault, while the third floor featured more research areas, with two large centered dark rooms flanked by bacteriology, biochemistry, and pathology laboratories. Experimentation using large and small animals filled the fourth floor, with rooms of cages; feed storage; and, anesthesia, operating observation, recovery, isolation, autopsy, and disposal rooms. The penthouse, like the basement, housed mechanical equipment.[43] The Research Institute also featured a "hot wing," a one-story unit with a basement built to the side of the main structure. A high-level Cobalt-60 radiation facility was completely segregated from the main block of the institute, with adjacent target room, instrument control, preparation, and radioactive waste disposal units. The Cobalt-60 facility included individual x-ray and electro-shielded laboratories; a large irradiation laboratory, isotope storage, and a Cockroth-Walton room. Cobalt-60 rods provided a source of electron and gamma ray irradiation for medical experiments. Radiation equipment for the Cobalt-60 facility sat in a heavily shielded basement directly below the Cockroth-Walton room. Institute personnel operated a security television from a penthouse room situated in the Cobalt-60 corner. The hot wing also included an "area for the study of potentially infectious agents."[44]

The fifth building designed for the aeromedical center at Brooks was the Altitude Laboratory, centered with the power plant, cooling tower, and small switching station to the rear of the main group. The Altitude Laboratory was most industrial and utilitarian structure among the primary buildings and, unlike the other main buildings, was steel-frame and clad in insulated aluminum paneling. Along one façade, the aluminum paneling could be removed for large doorway access to the interior. The Altitude Laboratory was divided into two distinct halves. On the east were briefing and oxygen classrooms; airmen and officers physical workout areas; a large area with indoctrination chambers; a night vision training room; and, a pressure suit training room. On the west was the human research area containing accumulator, climate, altitude, and pressure chambers, as well as an animal area with six individual facilities. Complementing the research activities in the western part of the Altitude Laboratory were multiple laboratories; study cubicles; and, an animal kennel room. Drawings for the Altitude Building are annotated March 1958, unlike the other sets of drawings for the aeromedical center. Design of this particular structure may be entirely the work of the Texas Architect-Engineer Association. (Drawings for the first four buildings at the aeromedical center date to late 1956 and early 1957.)[45] Finishing the middle 1950s aeromedical center at Brooks were the power plant and its ancillary structures. These buildings were the most forthrightly industrial of the planned group.[46]

Construction was underway for the five main buildings, the supporting power plant facilities, the street layout, parking lots, and landscaping during the late 1950s. In 1959, Senator Lyndon Johnson dedicated the new buildings as the United States Air Force Aerospace Medical Center. The center

was officially operational in mid-October. As a part of the reorganization of Air Force aeromedicine, the School of Aviation Medicine (and its incorporated School of Air Evacuation) formally moved from Randolph to Brooks. Major Otis O. Benson became the commander of the Aerospace Medical Center and the commandant of the School of Aviation Medicine. In an article for the *United States Air Force Medical Service Digest* in November 1959, he summarized the new capabilities and goals of the center. The state-of-the-art medical compound at Brooks was to support investigations of

> life-support systems for orbital satellites, biological and medical aspects of ionizing radiation, cardiac function and disease, medical standards and selection procedures in aviation, acclimatization to altitude, and bioclimatology of space flight.[47]

In November 1961, the Aerospace Medical Center at Brooks became the site for the Headquarters Aerospace Medical Division, under AFSC. The long tenure of the School of Aviation Medicine under the Air University had ended in 1959, followed by its assignment to Air Training Command for the two years prior to AFSC. The Aerospace Medical Laboratory at Wright-Patterson continued, but it became a subordinate unit to the Aerospace Medical Division at Brooks as a result of the 1961 command shift. A second aerospace medical research laboratory at Holloman Air Force Base in New Mexico (the 6571st Aeromedical Research Laboratory) also reported to the Aerospace Medical Division between December 1961 and the close of 1970. The other reporting components of the Aerospace Medical Division were the Air Force Hospital and Epidemiology Laboratory and the Personnel Research Laboratory, both at Lackland Air Force Base in San Antonio; and, the Arctic Aeromedical Laboratory near Fairbanks, Alaska.[48] With these changes, the Aerospace Medical Center became the United States Air Force School of Aerospace Medicine (USAFSAM).[49] AFSC immediately looked to expand the physical infrastructure for the USAFSAM at Brooks with the acquisition of the aeromedical center and its elevation in status to a division headquarters. The situation was ironic for a facility comprehensively designed over a long period and one just marginally operational. The Air Force had initiated planning toward the expansion in the second half of 1960, while the Aerospace Medical Center was still under Air Training Command. AFSC carried it forward and became the command responsible for the completion of the long-evolving aeromedical center at Brooks.[50]

As of early 1961, Air Training Command oversaw the first efforts toward a redesign of the aeromedical center at Brooks. The command hired the architectural-engineering firm of Smith, Hinchman & Grylls. The Detroit firm was one of national prominence and third-generation longevity (see discussion below). In February, Smith, Hinchman & Grylls completed drawings for a new master plan for the USAFSAM. The Smith, Hinchman & Grylls design added a large semicircular parking lot and diagonal walkways within the formerly open-turfed entry circle and doubled the number of main buildings from five to 10—filling in formerly grassy courtyards and small dispersed parking lots in the process. The new plan placed two large buildings outside the defining border road circumscribing the medical complex of the middle-to-late 1950s, a design decision that partially obliterated the balance of the Texas Architect-Engineer Association (Ellerbe & Company) plan. Two new mass parking lots offset the removal of key small lots, with one of these outside the border road. The Smith, Hinchman & Grylls plan also expanded the power plant and added a second cooling tower[51] (see Volume I, Plate 62 and Volume II, Plate 21). As of January 1962, master plans for the USAFSAM indicated even greater intentions to disregard the cohesive plan of the 1950s. As of this date, AFSC planned for seven more large buildings and three small ones at the site, concentrated to the east and south, and entirely outside the original border road.[52]

As built, the Smith, Hinchman & Grylls makeover of the aeromedical center included the five main buildings and power plant addition shown on their site plan of early 1961, and one of the large

structures planned as of 1962. Decisions for the other planned buildings awaited later developments, with buildings subsequently added one by one and designed by a variety of architectural firms between the middle 1960s and the end of the Cold War. The multibuilding complex marked a radical departure from the schools of aviation medicine erected before World War II. With the Smith, Hinchman & Grylls additions to the aeromedical center, visitors entered the complex through the double drive and either continued to one of the large parking lots on the periphery of the area or parked immediately in the new large semicircular lot. The broad expanse of the added Professional Building, also within the entry circle, defined first impressions. Smith, Hinchman & Grylls approached the design problem for the enlarged aeromedical center somewhat differently than had the architects of the 1950s. The architects broke the sustained horizontality of the facades through an introduction of vertical bands of windows and decorative panels, while continuing the aesthetics of a low, one-to-two-story profile for the buildings and relying on a veneer, narrow running-bond brick treatment over concrete block. Fenestration was plentiful, rather than sparse, with the rhythm of the banding closely spaced across front and rear facades.

Each of the added six structures designed by Smith, Hinchman & Grylls expanded the mission of the USAFSAM. The two floors of the Professional Building (Building 150) contained offices, administrative space, meeting rooms, and a medical intelligence library.[53] A two-story medical library (Building 155) sat to the immediate rear of the Professional Building. The front and rear façades featured sections of blue porcelain-enamel paneling set apart from one another by narrow vertical fenestration. A frame of plate glass panels above and at the sides, as well as at the entrance, completed the presentation. Secondary facades were windowless.[54] The library filled in former open space of the 1950s design—primarily three small landscaped parking lots. To its southeast, the Bioastronautics and Biodynamics Laboratory (Building 170) replaced one large courtyard and a portion of a parking lot. The one-story building (with partial penthouse) featured a three-story high-bay component at its southeast corner. Insulated metal paneling detailed portions of the high bay, as well as the penthouse. The Bioastronautics and Biodynamics Laboratory was geared toward Cold War space missions. The structure was to be

> the center of research and evaluations of reactions of humans and animals to varied problems of living under simulated space conditions. Here the regeneration of atmosphere under conditions encountered in space will be investigated, and studies will be made on energies encountered in space travel.

Its three units each accommodated interrelated space medicine missions. The east wing contained a lunar colony simulator, a two-man space cabin simulator, a one-man cabin space simulator, and a rotational flight simulator in the open area of the high bay. These simulators approximated conditions on the moon and in space. Engineers designed the lunar colony, in particular, to be as far from the centrifuge in the west wing (see below) as possible. The colony required this type of calibration to prevent a transfer of vibration and counteract interference with the simulator's instrumentation. The colony simulator featured "an environmental chamber (with an airlock) in which humans can live under conditions of temperature, humidity, and atmosphere approximating those on the moon." Engineers air-mounted the rotational flight simulator in the high bay to create "conditions of spatial disorientation and gravity which an astronaut would experience in outer space." Its air bearings allowed the simulator to rotate in any direction. The Military Engineer described the physics principles of this simulator to be the same as those for "a ping pong ball on the end of an air hose."[55] The west wing of the laboratory contained a human centrifuge in a large circular room (Plate 22). The centrifuge area required special design of the roof and walls to withstand the aerodynamic currents caused by the rotation of both human and animal centrifuge equipment. This part of the

Plate 22: The Rucker Company. Gondola for the Human Centrifuge, Bioastronautics and Biodynamics Laboratory (Building 170), Brooks Air Force Base, 1961. Courtesy of the History Office, Brooks Air Force Base.

Bioastronautics and Biodynamics Laboratory was reinforced concrete construction, separated from the rest of the building by 1.5 inches. The walls and floor of the centrifuge area were not integrated with the ceiling, which featured an entirely segregated support system. The torque created by the centrifuge when in motion also posed an engineering challenge to the laboratory's site. Soil conditions indicated that the foundation would turn with the centrifuge unless engineers took special precautions. To counteract this effect, engineers designed an 18-foot-diameter reinforced concrete base for the centrifuge that extended 23.5 feet below the level of the floor. Seven concrete piers with radiating lateral supports also augmented the foundation system for the room as a whole. The third unit of the Bioastronautics and Biodynamics Laboratory connected the east and west wings, and functioned as a space where scientists could evaluate the experiments run in the special rooms of the wings.[56]

The segregated building for human centrifuge and its equipment received the most discussion in the engineering press. The circular shape of the room containing the centrifuge reflected the structural needs of the building. Design of the room directly paralleled that of the Navy's human centrifuge of 1949-1951 at the Naval Air Development Center in Johnstown, Pennsylvania. The Navy's centrifuge predated that at Brooks by more than a decade, and as such pioneered engineering for this kind of facility. As one would expect, there are both strong similarities between the two centrifuges and differences—the latter were improved engineering solutions appropriate to the passage of a decade. The engineers from the Bureau of Yards and Docks had decided on a circular building of reinforced concrete, as would Smith, Hinchman & Grylls for the Air Force. Navy engineers had also devised a

special structural solution for the design of the centrifuge ceiling. They had hung the ceiling and floor of the centrifuge chamber from the roof of the building. The Air Force centrifuge modified this approach for the facility at Brooks. Both the Navy and the Air Force faced especially difficult challenges in designing foundation systems that would work for their centrifuges. The Navy at first planned for a battered pile foundation, radiating outwards, but concluded that the dynamic loading of the operating centrifuge would cause the foundation to fail. Navy engineers literally selected a new site for the centrifuge (at the preexisting three-laboratory Naval Air Development Station) in order to find solid rock. (Although unverified, the planned location for the Navy's human centrifuge was probably the School of Aviation Medicine in Pensacola. The discarded first site was of sandy type.) The Navy's use of bedrock to create a deep, immobile foundation in the late 1940s is paralleled by the Air Force's turn to a 23.5-foot-deep reinforced concrete foundation in the early 1960s. Both the Air Force and the Navy also faced similar constraints in designing the interior equipment of their human centrifuges. As planned, the Brooks centrifuge had a rotor arm 20 feet long, with a gondola at its outer end (see Plate 22). Engineers designed the gondola for up to a 600-pound payload. Its chamber was nine feet long and six feet in diameter. The suspension of the gondola allowed rotation between 0 and 90 degrees. The centrifuge could create gravity forces up to 50 Gs at a rate of one G per second at onset, and capable of reaching 50 Gs in 60 seconds. The gondola could move at 85 miles per hour at maximum G-forces. In comparison, the Navy's centrifuge at Johnstown featured a rotor arm 50 feet long. The Navy's gondola was engineered as an oblate spheroid decompression chamber, and was of aluminum-balsa construction to minimize any dead weight. Like that of the Air Force at Brooks, the gondola for the human centrifuge at the Naval Air Development Center accommodated a live load up to 600 pounds. Its maximum gravitational forces loading was 40 Gs. The Air Force equipment at Brooks improved the G loading by 25%, and did so with a much smaller rotational arm. Maximum payload weight for both centrifuges remained constant.[57]

The final large buildings designed by Smith, Hinchman & Grylls in 1961 at Brooks were outside the road bordering the original 1950s aeromedical center. The one-story (with two partial penthouses) Bionucleonics Laboratory (Building 175) sat to the southeast of the Altitude Building and was detailed very similarly to the Professional Building. A large courtyard, open to the sky, divided the Bionucleonics Laboratory in two distinct facilities. The eastern two-thirds of the building featured over 100 specialized biochemistry laboratories. The western unit had a mission somewhat parallel to ones found at the Army's Fort Detrick in Maryland and at the Center for Disease Control in Atlanta. The segregated area contained a virus and rickettsia media preparation room, with an associated virus and parasite environmental exposure chamber, inoculation room, agent assay laboratory, cold storage room (4 degrees Centigrade [C]), incubation room (37 degrees C), exposed animal room, tissue pathology laboratory, autopsy room, ultraviolet air lock, and support units. The western unit also included a bacteria and mycoses media preparation laboratory, with the same range of associated special test facilities.[58] The Bionucleonics Laboratory had a space-studies mission, similar to the mission of the Bioastronautics and Biodynamics Laboratory. Aeromedical center personnel used the laboratory to test live animals exposed with viruses, microorganisms, bacteria, and parasitic fungi in conditions that simulated proton and cosmic space radiation. The testing helped establish appropriate radiation shielding for the Air Force Manned Orbiting Laboratory, as well as for NASA's space suits and spacecraft.[59]

The Military Engineer described the construction program for the Bionucleonics Laboratory as among the most difficult of the Smith, Hinchman & Grylls efforts at Brooks. The building necessitated the incorporation of safeguards and equipment to protect personnel and required an unusual environment to sustain highly delicate work. A shielded area featured three cells enclosed in laminated layers of 2.5-inch-thick steel plate lined with lead and encased in 18 inches of concrete. Engineers used aged steel ship plate from naval vessels for the shielding. The aged steel helped to

ensure a low level of molecular activity and a low background radiation count. Again, engineers faced special foundation challenges due to the weight of the shielded cells. For the Bionucleonics Laboratory, Smith, Hinchman & Grylls turned to deep piles with bell-bottom caissons. The site's soil was unstable to 28 feet, a factor that required piles to be punched to below this depth. For the heaviest portion of the laboratory, piles extended to more than 40 feet and were 36 inches in diameter. Both the nuclear and biological test sections of the laboratory also necessitated precise engineering and multiple precautions beyond that of the cells' shields. All natural radiation was kept at a minimum to ensure experimental accuracy. Engineers took unusual steps to achieve this precision.

> Every piece of material used in construction must be tested for radiation count which must fall within certain low limits of tolerance. All structural work in the area and on fabrication of lead and steel will be done by burning and welding. The use of oil in machining any part of the steel to go into the shielded zone is prohibited because the radiation count from molecular action in the oil would create conditions inimical to the studies to be conducted.

The biological area necessitated protective features to prevent airborne movement of bacteria, viruses, and infectious agents. This area included facilities classed as "cold," "hot," and "extra hot." Ultraviolet air locks existed between these facilities. Other control measures included reduced air pressures, nonrecirculating ducted air, and gas and steam autoclaves for exit from the extra-hot test areas.[60]

The remainder of the Smith, Hinchman, & Grylls design for the expansion of the USAFSAM during the 1960s included several additional buildings. The Vivarium Support Facility (Building 185) sited to the east of the border road was the fifth building of the initial group of 1961. This structure functioned as an animal kennel and clinic. The Vivarium Support Facility featured large rooms of single-caged monkeys and an oversized room of colony-caged monkeys, with about 40 percent of the single-story structure holding rows of dog kennels with a center dog run. The kennel and clinic was windowless, with a partial penthouse.[61] In 1961, AFSC also commissioned Smith, Hinchman & Grylls to begin a quarantined animal holding area in the far southwestern corner of the base (Buildings 1004-1019). The segregated compound first featured only a large animal unit, with rows of individual stalls. As of 1963-1966, AFSC erected more quarantine structures, including multiple dog kennels, as well as facilities for primates, swine, and opossums. By the late 1970s, the animal holding area also added a morgue.[62] Although AFSC did not expand the USAFSAM as aggressively as it had anticipated in January 1962, the command did commission Smith, Hinchman & Grylls to design one more major structure as a part of the early 1960s efforts. The Biosystems Research Laboratory (Building 140) directly continued the aesthetics of the other early 1960s buildings added to the USAFSAM. AFSC sited the laboratory to the southwest of the original aeromedical center, outside the border road for the complex. The one-story structure, with partial penthouse, featured more than 100 individual biology and chemistry laboratories.[63] The Bioastronautics and Biodynamics Laboratory, Bionucleonics Laboratory, and Biosystems Research Laboratory all addressed interrelated issues of virus, bacteria, microorganisms, and fungi behavior under conditions of varied radiation shielding for planned Air Force and NASA space missions.[64]

After 1961-1963, AFSC continued to enlarge the USAFSAM area through the addition of individual structures. The command also sometimes significantly expanded and modified buildings already in place. Later aeromedical buildings of note included an electronics science laboratory designed by Bullock, Wright & Miller in 1964 (Building 176), an electron acceleration laboratory by Phelps Simmons & Associates in 1964 (Building 186), an aerospace laboratory by Bernard Johnson

Engineers in 1971 (Building 110), and an ejection seat facility by base civil engineering in 1984 (Building 162). Of note, AFSC erected key aeromedical and space-project laboratories at locations fully removed from the USAFSAM area beginning in 1963. These individual buildings included a telemetry data analysis laboratory for satellite communications studies of 1963 (Building 749), a field training facility with a parachute harness hanging trainer of 1964-1973 (Building 820), a radiation laboratory of 1968 (Building 803), an epidemiological laboratory of 1969 (Building 930), the Remote Lunar Sample Storage Facility of 1955—modified by NASA in 1975 (Building 950), and the Human Resources Research Facility of ca.1977 (Building 578).[65]

AFSC conducted studies at the USAFSAM and in its other specialized laboratories at Brooks throughout the 1960-1991 period to support general aeromedical needs, with an increasing focus on the space mission. After World War II, the Army Air Forces had envisioned an aeromedical center with simpler goals, even as scientists looked toward supersonic, high-altitude flight and space travel. In late 1949, Headquarters Air Force had described the future aeromedical center as a basic support institution that would review "rated personnel [pilots]" "every five (5) years until forty (40) years old, and every three (3) years thereafter" (see Volume I, Part II). From its very first years during the early 1960s, however, research and experimentation at the USAFSAM were more ambitious. In one example, the aeromedical center at Brooks supported the NASA Project Mercury test shots. Center personnel designed and tested the life-support packs worn by monkeys launched from facilities on Wallops Island, Virginia. NASA also launched mice and bacteria in experimental payloads atop Atlas missiles using equipment (biopacks) designed at Brooks. Other space-related studies for NASA were many, from zero-gravity experimentation to atmospheric tests to pressurized space suits (Plate 23) to space food.[66] Brooks additionally served as a secondary NASA storage site for lunar rocks,

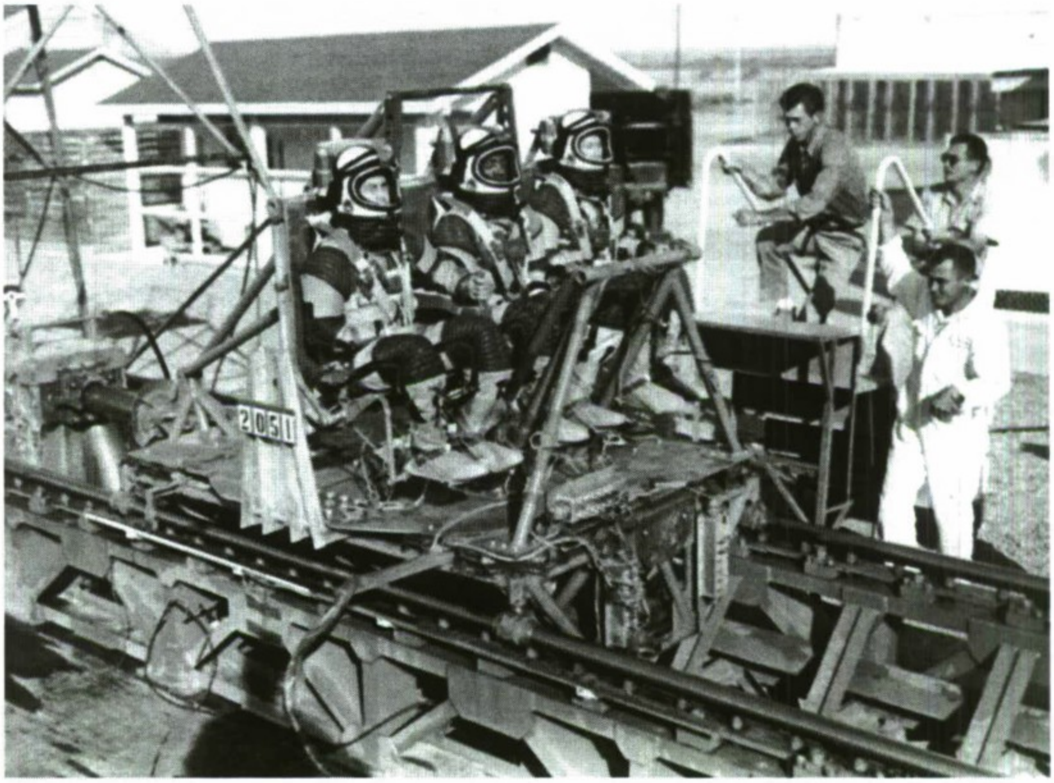

Plate 23: Pressure Suits in Test on the Daisy Decelerator Track at Holloman Air Force Base for the Aerospace Medical Center / United States Air Force School of Aerospace Medicine, ca. early 1960s. Courtesy of the History Office, Brooks Air Force Base.

pebbles, soil, and dust, gathered during the Apollo missions of 1969-1972. NASA adapted an existing one-story reinforced concrete communications building of the middle 1950s for the special mission (the Remote Lunar Sample Storage Facility). The storage facility featured an underground nuclear blast-resistant vault operated under stringent conditions, with moon samples stored in nitrogen-filled, stainless steel containers.[67]

Personnel of the Aerospace Medical Division at Brooks also contributed to the medical needs of the Air Force during the Vietnam War. Flight nurses trained at Brooks assisted in the airlift of patients out of Vietnam, with the base acting as a center of aeromedical evacuation efforts during the conflict. In one major specialty project of 1966-1968, personnel of the USAFSAM worked with the Brunswick Corporation toward the development of an air-transportable hospital. The USAFSAM started the project with an in-house definition phase during 1966 and 1967. Brunswick Corporation received the development contract for prototype facilities in December 1967. The USAFSAM desired the transportable hospital to replace an existing 36-bed air-transportable tent dispensary. The basic unit of the seven-module hospital compared in its size to those established for TAC's Bare Base program in early 1969[68] (see Volume I, Part III and Volume II, Chapter 3). The transportable hospital was about 9 feet, 4 inches high, with each prefabricated unit folding down to containers of 9 feet, 4 inches by 9 feet, 4 inches by 13 feet. In its collapsed mode for shipment, each module stored 30 days of supplies. The hospital resembled World War II temporary barracks and halls in its assembled dimensions, at 37 feet wide and 91 feet long. In September 1969, the Brunswick Corporation delivered the Mark I prototype of the Modular Air Transportable Hospital to North Field, South Carolina, for TAC's Bare Base demonstration of October. TAC ran Category III tests on the hospital at Seymour-Johnson Air Force Base in North Carolina, through the 4th Tactical Hospital there. The Surgeon General's Office and Headquarters AFSC subsequently decided to ask Brunswick to incorporate modifications identified through TAC testing and finalize the design of the air-transportable hospital. The Modular Air Transportable Hospital featured seven prefabricated units, each 13 by 37 feet. The Air Force flew the units to sites on C-130s, with three prefabricated modules transported per aircraft. The prefabricated hospital saved lives in a theater of war. Men quickly assembled the buildings on location.[69]

"Relocatable," "modular" facilities assumed a level of vital importance during the escalation of the Vietnam War, with active testing at Eglin Air Force Base as of 1967 for a variety of structures contracted through AFSC's Air Force Civil Engineering Center at Wright-Patterson (see Volume II, Chapter 3). The prefabricated modular hospital was part of the Modular Relocatable Facilities Program by mid-1969. The program included dormitories, officers quarters, chapels, medical facilities, dining halls, and schools.[70] The Modular Air Transportable Hospital (Plate 24) was also known as a 100-man casualty staging unit. AFSC again hired the Brunswick Corporation to develop a Mark II prototype for an improved air-transportable hospital in early 1971. The command tested this prototype in the climatic hangar at Eglin in 1972. Subsequently, the Mark II air-transportable hospital became part of TAC's Bare Base program.[71] Other shippable medical facilities included 10- and 25-bed dispensaries. These were presumably smaller combinations of the same basic modules that comprised the hospital. The Air Force awarded Elder-Oilfield, Incorporated, of Houston, the primary procurement contract for the steel rigid-frame, plywood-walled relocatable structures. Although the Air Force shipped most to Southeast Asia, others went to Korea, Turkey, and Greece during 1969-1972. The medical facilities, like other prefabricated infrastructure shipped overseas, also found occasional use in the continental United States. The Air Force set up one 100-man hospital at Scott Air Force Base in Illinois in early 1971, shipping another to the Veterans Administration in Los Angeles the next year for use there. Air Force Logistics Command (AFLC) stored excess hospital and dispensary modules at McClellan Air Force Base in California, along with other prefabricated building units (see Volume II, Chapter 10).[72]

Plate 24: Brunswick Corporation. Modular Air Transportable Hospital, 1968-1972. In *Aerospace Medical Division: Twenty-Five Years of Excellence 1961-1986.*

Other activities occurred at Brooks during the late Cold War. One major effort was an epidemiological study of the effects of Agent Orange on veterans who had been exposed to aerial spraying while overseas. Congress committed the Air Force to a 20-year study of Agent Orange effects in 1979, known as the Ranch Hand Study (derived from the name of the aerial spraying during the Vietnam War, Operation Ranch Hand)—and later, as the Air Force Health Study. The Agent Orange studies included physical exams administered every few years and continuing into 2002.[73] During the 1980s, the Aerospace Medical Division at Brooks also established new programs in chemical defense, life support, and clothing (leading to the Life Support System Program Office); aeromedical systems; crew escape technologies (aircraft ejection seat studies); analysis of missile fuel toxicity; work toward nerve agent antidotes; and, linkage of crew protection and readiness, laboratory studies, and weapons systems production (through the Air Force Human Resources Laboratory).[74] At the close of the war, organizational changes within the Department of Defense, the Air Force, and AFSC, initiated a streamlining process for the Air Force medical mission. The Aerospace Medical Division became the Human Systems Division in early 1987. Under Project Reliance, more encompassing changes across the Department of Defense included an Air Force shift toward consolidated laboratories. AFSC created four clustered laboratory groups: the Phillips Laboratory at Kirtland Air Force Base in New Mexico (with individual laboratories also at Edwards and Hanscom); the Wright Laboratory at Wright-Patterson Air Force Base in Ohio; the Rome Laboratory at Griffiss Air Force Base in New York (with facilities at Hanscom and off site in upstate New York); and, the Armstrong Laboratory at Brooks. Activated in mid-December 1990, the Armstrong Laboratory included the Human Resources, Drug Testing, and Occupational and Environmental Health Laboratories at Brooks, along with the School of Aerospace Medicine on base, and the Aerospace Medical Research Laboratory at Wright-Patterson.[75]

Key Associated Architects and Engineers

Architects of national prominence associated with the design of major buildings at, and planning for, Brooks Air Force Base during the Cold War included:

- Ellerbe & Company, of Minneapolis-St. Paul; and,
- Smith, Hinchman & Grylls, of Detroit.

These two firms were substantially responsible for the planning and appearance of the Aerospace Medical Center of the late 1950s and early 1960s. The role of the Texas Architect-Engineer Association of Austin appears to be derivative of Ellerbe & Company, but conclusive research has not occurred.

Ellerbe & Company

Ellerbe & Company had begun work toward the aeromedical center at Brooks during 1951, with drawings completed as of 1953. Disagreements between Ellerbe & Company and the Air Force regarding its design for a standardized hospital, as well as delays in the Brooks project, removed the Minneapolis firm from the design process—with the first buildings carried to fruition by the regional collaborative firm of the Texas Architect-Engineer Association of Austin. Ellerbe & Company continues today as Ellerbe Becket, a firm of 92 years longevity. Ellerbe & Company is historically known for its work for the Mayo Clinic in Rochester, Minnesota, and for a wide variety of hospitals, medical centers, and clinics. Joan Whaley Gallup, an architect and director of health care planning at Ellerbe Becket, recently wrote *Wellness Centers: A Guide for the Design Professional*—the first comprehensive discussion of a medical facility type pioneered by Dr. Ken Cooper in Texas during the 1970s and developed by the Ellerbe firm thereafter. Multiple hospital complexes of the past decade are among the recent work of Ellerbe Becket, including the Mount Sinai Medical Center in New York, the Northwestern Memorial Hospital in Chicago, the Palo Alto Medical Foundation in California, and the Texas Children's Hospital and Baylor College of Medicine. The firm has also designed Hospital 31 in Moscow and the Yonsei University Medical Center in Seoul, South Korea. Two facilities that Ellerbe Becket has undertaken in the past five years deserve special note. Their design for the National Archives II repository in College Park, Maryland, took a Presidential Design Award in 1995, while their design for the United States Department of Agriculture Plant Germplasm Quarantine Center in Beltsville, Maryland, is a prototype for a biosafe Level III quarantine laboratory and attached greenhouse.[76]

Smith, Hinchman & Grylls

Smith, Hinchman & Grylls continued design for the major buildings program at the Aerospace Medical Center during 1961-1963. The firm contributed a second sizable group of buildings to the center, although Smith, Hinchman & Gryll's additions substantially obliterated the facility's master plan of the early and middle 1950s,. The Smith family of architects dated to the middle 19th century in Detroit, begun by Sheldon Smith in 1853 and continued through his son Mortimer L. Smith (1840-1896). Fred L. Smith (1862-1941) was the senior partner of Smith, Hinchman & Grylls, a firm known for many types of large civic buildings, including hotels, office blocks, schools, and churches. Maxwell H. J. Grylls (1865-1942), an immigrant architect from Britain, joined Fred Smith in the first decade of the 20th century.[77] Smith, Hinchman & Grylls continued after the early 1940s with the name of the original partners, training many major architects of the region. The three partners of Leinweber, Yamasaki & Hellmuth—Joseph Leinweber, Minoru Yamasaki, and George Hellmuth—for example, all worked as draftsmen in Smith, Hinchman & Grylls during the 1940s. The Army hired Leinweber, Yamasaki & Hellmuth in 1951 to continue work begun five years earlier by Smith,

Hinchman & Grylls on the design of a complex of research, development, and test laboratories for the Detroit Arsenal. The High Temperature Building at the arsenal was the Army's large climatic test chamber. The unique facility paralleled the climatic hangar at Eglin Air Force Base under ARDC / AFSC of this same period.[78] Smith, Hinchman & Grylls were also involved in another high-profile R&D project for the American military during the early Cold War. The Glenn L. Martin Company commissioned the firm to design Air Force Plant PJKS near Denver in 1955. The plant served as a design, assembly, and testing facility for the Titan I intercontinental ballistic missile (ICBM). Ralph M. Parsons designed the test stands at the site (see Volume I, Plate 43 and Volume II, Chapter 6).[79] Like many companies post-World War II, Smith, Hinchman & Grylls has continued to grow through acquisition. In 1971, the firm acquired Johnson, Johnson & Roy of Ann Arbor, Michigan; in 1996, Keyes Condon Florance, Architects, of Washington, D.C.; in 1997, Stone Marraccini Patterson of San Francisco; and, in 1999, Architects Four (Ann Arbor, Michigan), with Smith, Hinchman & Grylls changing names to SmithGroup in 2000. Although the firm's work did not historically focus on medical facilities, some prominent commissions of this type are a part of the SmithGroup portfolio. In 1947, Smith, Hinchman & Grylls designed the Wayne University Medical Center in Detroit (see Volume I, Part III), while in 1994 the firm designed St. John's Health Center in Los Angeles.[80]

---

[1] Karen J. Weitze, *Aeromedical Evacuation Annotated Bibliography* (Austin, Texas, and, Colton, California: through Earth Tech, Inc., for the Air Force Center for Environmental Excellence, November 1994), *passim.*

[2] Major General Otis O. Benson, Jr., "From Hazelhurst to Brooks: A Saga of Aeromedical Pioneering," *United States Armed Forces Medical Journal* 10, 11 (November 1959): 1273-1285.

[3] Weitze, *Aeromedical Evacuation Annotated Bibliography*, 1994.

[4] Benson, "From Hazelhurst to Brooks," *United States Armed Forces Medical Journal*, November 1959, 1277.

[5] *Ibid*, 1279.

[6] For all chapters that have a standard Army Air Forces and Air Force command lineage, readers should reference Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 of *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989), for multiple baseline facts. Information contained in the Mueller volume includes: source of the installation's name; current and past names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and a year-by-year indexing of units assigned to the base. While the Mueller volume is not flawless (there are omissions and some errors), it is an invaluable tool for tracing and linking many specifics at Air Force installations.

[7] Benson, "From Hazelhurst to Brooks," *United States Armed Forces Medical Journal*, November 1959, 1278.

[8] Mueller, *Active Air Force Bases*, 1989, 49-56.

[9] *Ibid*, 53.

[10] *Ibid.*

[11] Martha Doty Freeman, "Historic Context: Brooks Air Force Base, An American Flying Field," in Duane E. Peter, Maynard B. Cliff, Joe Freeman, and Kimberly L. Kane, *Brooks Air Force Base Historic Preservation Plan* (Plano, Texas: Geo-Marine, Inc., for Air Force Materiel Command, March 1995).

[12] Benson, "From Hazelhurst to Brooks," *United States Armed Forces Medical Journal*, November 1959, 1279-1280.

[13] Harry G. Armstrong, Colonel, Medical Corps, School of Aviation Medicine, to the Air Surgeon, "U.S. Air Force Aeromedical Center," memorandum with attachments, 29 December 1947, in *A Proposed United States Air Force Aeromedical Center August 1946 – August 1949*. See also, the detailed presentation of the planning process for the Air Force aeromedical center in Volume I, Part III.

[14] *Architectural Record*: "U.S. Naval Hospital, Beaufort, S.C.," 107, 4 (April 1950): 101-110, and, "Pavilion Plan Favored for Hospitals," 112, 3 (September 1952): 177-178.

[15] "U.S. Naval Research and Development," in *Space Medicine in Project Mercury*, posted at www.lsda.jsc.nasa.gov/books/mercury/ch01.htm.

[16] Edward B. Alcott and SMSgt. Robert C. Williford, *Aerospace Medical Division: Twenty-five Years of Excellence 1961-1986* (Brooks Air Force Base: History Office, Aerospace Medical Division, Air Force Systems

Command, 1986), 14-16, 162. The Air University functioned autonomously at a command level as of 1946 and did not come under Air Training Command until 1978.
[17] Benson, "From Hazelhurst to Brooks," *United States Armed Forces Medical Journal*, November 1959, 1282.
[18] "Reclama on Construction Program Item," attached to Memorandum on Aeromedical Center from Dan C. Ogle, Deputy Surgeon General, to Major General P.W. Timberlake, Director of Installations, 18 April 1951, and Memorandum on Aeromedical Center from Harry G. Armstrong, Surgeon General, to Mr. Burden, Office, Secretary of the Air Force, 9 February 1951, both in *USAF School of Aviation Medicine Correspondence, Memoranda, Studies, and Plans, January 1950 – December 1953.*
[19] Benson, "From Hazelhurst to Brooks," *United States Armed Forces Medical Journal*, November 1959, 1282-1283.
[20] Posted at www.ellerbebecket.com.
[21] Posted at www.mayo.edu.
[22] Posted at www.ellerbebecket.com. The laminated arches for the two Army Air Forces four-bay hangars at Vandalia, Ohio, designed by Anton Tedesko of Roberts & Schaefer, superceded those of Northwest Airlines in St. Paul, with a 177-foot span. See Volume I, Part II, and, Volume II, Chapter 14.
[23] Heather Puckett and Janet Ostashay, *Historic Building Inventory and Evaluation of Cold War-Era Buildings at Brooks Air Force Base* (Colton, California: Earth Tech, Inc., and Planning Consultants Research, October 1998), 3-16. Ellerbe & Company had also designed the courthouse for St. Paul in about 1940, working with Holabird, Root & Burgee of Chicago—another key firm hired by Air Materiel Command in the late 1940s. See *Architectural Record* 87, 6 (June 1940): 22.
[24] Sarkis M. Bagdoyan, Bureau of Yards and Docks, "Unique laboratory houses human centrifuge," *Civil Engineering* 21, 11 (November 1951): 21-24; "Human Centrifuge Test Building," *Architectural Record* 112, 3 (September 1952): 184-185; "Acceleration Experience Provided by Centrifuge," *The Marshall Star* 1, 6 (2 November 1960): 2; and, "Naval Air Development Station" and "Naval Air Development Center," within a chronology of 1946-1949 posted at www.history.navy.mil/branches/avch6.htm. See also, Note 14.
[25] Headquarters United States Air Force, *History of the Assistant Chief of Staff, Installations 1 January – 30 June 1956*, volume 7, 55.
[26] Headquarters United States Air Force, *History of the Assistant Chief of Staff, Installations 1 July – 31 December 1955*, volume 6, 72.
[27] Mueller, *Active Air Force Bases*, 1989, 54-56.
[28] Weitze, *Aeromedical Evacuation Annotated Bibliography*, 1994, *passim.*
[29] Puckett and Ostashay, *Historic Building Inventory and Evaluation of Cold War-Era Buildings at Brooks Air Force Base*, 1998, 3-25.
[30] *History of the Assistant Chief of Staff, Installations 1 July – 31 December 1955*, volume 6, 72.
[31] Lenore Fine and Jesse A. Remington, *The Corps of Engineers: Construction in the United States* volume in *United States Army in World War II The Technical Series* (Washington, D.C.: Office of the Chief of Military History, 1972), 528-529.
[32] Robert J. Fleming, Jr., Adolf Kroeber, and George L. Hahn, "Construction of Aerospace Medical Center," *The Military Engineer* 357, 54 (January-February 1962): 9-11.
[33] Henry F. Withey and Elsie Rathburn Withey, *Biographical Dictionary of American Architects (Deceased)* (Los Angeles: Hennessey & Ingalls, Inc., 1970), 452.
[34] Roxanne Kuter Williamson, *Austin, Texas: An Architectural History* (San Antonio: Trinity University, 1973), xxi.
[35] Fleming, Kroeber, and Hahn, "Construction of Aerospace Medical Center," *The Military Engineer*, January-February 1962, 11.
[36] Texas Architect-Engineer Association, "School of Aviation Medicine Brooks AFB Texas General Layout," December 1956.
[37] Fleming, Kroeber, and Hahn, "Construction of Aerospace Medical Center," *The Military Engineer*, January-February 1962, 11.
[38] Texas Architect-Engineer Association, "School of Aviation Medicine Brooks AFB Texas Academic Building," elevations and floor plans, drawing 29-03-01, December 1956.
[39] Benson, "From Hazelhurst to Brooks," *United States Armed Forces Medical Journal*, November 1959, 1285.
[40] Texas Architect-Engineer Association, "School of Aviation Medicine Brooks AFB Texas Flight Medicine Laboratory," elevations and floor plans, drawing 32-39-01, December 1956.

[41] Texas Architect-Engineer Association, "School of Aviation Medicine Brooks AFB Texas Research Laboratory Shops," elevations and plans, drawing 35-06-01, February 1957.
[42] Fleming, Kroeber, and Hahn, "Construction of Aerospace Medical Center," *The Military Engineer*, January-February 1962, 11.
[43] Texas Architect-Engineer Association, "School of Aviation Medicine Brooks AFB Texas Research Institute Building," elevations, plans, and details, drawing 32-11-01, February 1957.
[44] Benson, "From Hazelhurst to Brooks," *United States Armed Forces Medical Journal*, November 1959, 1285.
[45] Texas Architect-Engineer Association, "School of Aviation Medicine Brooks AFB Texas Altitude Laboratory," elevations and plans, drawing 28-12-01, March 1958.
[46] Texas Architect-Engineer Association, "School of Aviation Medicine Brooks AFB Texas Heating & Cooling Plant," elevations, drawing 26-05-01, February 1957.
[47] Major General Otis O. Benson, Jr., "USAF School of Aviation Medicine of the Aerospace Medical Center," *United States Air Force Medical Service Digest* 10, 10 (November 1959): 2-3.
[48] Alcott and Williford, *Aerospace Medical Division*, 1986, 28.
[49] Puckett and Ostashay, *Historic Building Inventory and Evaluation of Cold War-Era Buildings at Brooks Air Force Base*, 1998, 3-21; Mueller, *Active Air Force Bases*, 1989, 56.
[50] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1960*, volume 8, 28.
[51] Smith, Hinchman & Grylls Association, Inc., "School of Aviation Medicine Brooks AFB Texas Site Development," February 1961.
[52] Air Force Systems Command, "Master Plan Basic Mission Development Plan Brooks Air Force Base," 1 January 1962.
[53] Smith, Hinchman & Grylls Association, Inc., "School of Aviation Medicine Brooks AFB Texas Professional Building," elevations and plans, drawing AW 30-03-01, February 1961.
[54] Smith, Hinchman & Grylls Association, Inc., "School of Aviation Medicine Brooks AFB Texas Library Building," elevation, drawing AW 29-04-01, February 1961.
[55] Fleming, Kroeber, and Hahn, "Construction of Aerospace Medical Center," *The Military Engineer*, January-February 1962, 11.
[56] *Ibid*, 10-11; and, Smith, Hinchman & Grylls Association, Inc., "School of Aviation Medicine Brooks AFB Texas Bioastronautics & Biodynamics Laboratory," elevations and plans, drawing 32-11-02, February 1961.
[57] Fleming, Kroeber, and Hahn, "Construction of Aerospace Medical Center," *The Military Engineer*, January-February 1962, 11; Bagdoyan, "Unique laboratory houses human centrifuge," *Civil Engineering*, November 1951; and, "Acceleration Experience Provided by Centrifuge," *The Marshall Star*, 2 November 1960.
[58] Smith, Hinchman & Grylls Association, Inc., "School of Aviation Medicine Brooks AFB Texas Bionucleonics Laboratory," elevations and plans, drawing 32-11-01, February 1961.
[59] Andrea Urbas and Paige Peyton, *Brooks AFB, Texas: Man-in-Space Era Historic Building Inventory and Evaluation*, Draft (Colton, California: Earth Tech, Inc., for Air Force Materiel Command, February 2001), 4-22.
[60] Fleming, Kroeber, and Hahn, "Construction of Aerospace Medical Center," *The Military Engineer*, January-February 1962, 10.
[61] Smith, Hinchman & Grylls Association, Inc., "School of Aviation Medicine Brooks AFB Texas Vivarium Support Facility," elevations and plans, drawing 34-08-01, February 1961.
[62] Diane Williams, handwritten notes taken from individual drawings in the civil engineering vault at Brooks Air Force Base, December 2000; Urbas and Peyton, *Brooks AFB, Texas: Man-in-Space Era Historic Building Inventory and Evaluation*, Draft, 2001, 4-28 – 4-36.
[63] Smith, Hinchman & Grylls Association, Inc., "School of Aviation Medicine Brooks AFB Texas Biosystems Research Laboratory," elevations and plans, drawing 32-11-03, January 1963.
[64] In addition to detailing the individual functions for the laboratories contained in each building, the Army Corps of Engineers assigned these three structures a sequential number in the same design series—another indication of their direct mission linkage.
[65] Diane Williams, "Brooks AFB: Building Notes," typed list of individual buildings reviewed by real property number, date of construction (including key additions and modifications), and architects, December 2000.
[66] Urbas and Peyton, *Brooks AFB, Texas: Man-in-Space Era Historic Building Inventory and Evaluation*, Draft, 2001, *passim*.
[67] Puckett and Ostashay, *Historic Building Inventory and Evaluation of Cold War-Era Buildings at Brooks Air Force Base*, 1998, 3-23 – 3-24.

[68] Frank A. Norcross Jr., "TAC Base Shelter Program," *Air Force Civil Engineer* 10, 2 (May 1969): 30-31.
[69] Alcott and Williford, *Aerospace Medical Division*, 1986, 51-54, 165; United States Air Force Medical Service, *A Semi-Annual History of the Office of the Surgeon General 1 July – 31 December 1969*, 51; and, Air Force Systems Command: *History of the Aerospace Medical Division 1 July 1967 – 30 June 1968*, volume 1, 47 and 49, and volume 2, tab 12; *History of the Aerospace Medical Division 1 July 1968 – 31 December 1969*, volume 1, 49-51; and, *History of the Aerospace Medical Division 1 July 1969 – 30 June 1970*, volume 1, 60.
[70] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1969*, volume 3, 37.
[71] Air Force Systems Command, *History of the Aerospace Medical Division 1 July 1971 – 30 June 1972*, 108-109.
[72] Headquarters United States Air Force, *History of the Directorate of Civil Engineering*: July 1969 – June 1972, *passim*.
[73] Puckett and Ostashay, *Historic Building Inventory and Evaluation of Cold War-Era Buildings at Brooks Air Force Base*, 1998, 3-27.
[74] *Ibid*, 3-27 – 3-30.
[75] Edward B. Alcott, "Contributions of the Human Systems Center at Brooks AFB to Air Force History," typescript of a draft essay composed for the History Office at Headquarters United States Air Force, 21 December 1995, 23-24, 27-28.
[76] Posted at www.ellerbebecket.com.
[77] Withey and Withey, *Biographical Dictionary of American Architects (Deceased)*, 1970, 252, 559-560.
[78] Karen J. Weitze, "Historic Context and Historic American Buildings Survey (HABS) Level IV Cards for Cold War Architectural Resources Post-1945," in *Detroit Arsenal Cultural Resources Management Plan* (Plano, Texas: Geo-Marine, Inc., for Army Materiel Command, October 1996).
[79] Joseph Trnka, Terri Wessel, and William Manley, *Historic Building Inventory and Evaluation of Air Force Plant PJKS, Jefferson County, Colorado* (Colton, California: Earth Tech, Inc., and William Manley Consulting, for Air Force Materiel Command, Aeronautical Systems Center, February 1997), 3-19.
[80] Posted at www.smithgroup.com.

Chapter 3: Edwards Air Force Base

Historic Missions of the Cold War

Edwards Air Force Base in Southern California offered a nearly perfect location and climate for aircraft flight testing during the Cold War. The installation was also highly suitable for large rocket motor static testing and other types of specialized research and test that required a dry, isolated setting. The Air Research and Development Command (ARDC) and its successor Air Force Systems Command (AFSC) selected the dry lake bed areas northeast of Los Angeles for Edwards for many of the same reasons that the Army, Navy, and Air Force developed major desert test installations at White Sands Proving Ground (Missile Range) in New Mexico (north of El Paso near Holloman Air Force Base); China Lake, California (north of Edwards); and, Dugway Proving Ground and Utah Test and Training Range (UTTR) west of Salt Lake City. From as early as 1942, Army Air Forces Materiel Command recognized the value of the Mojave Desert location for a flight test base and established a test installation on the northwest edge of Rogers Dry Lake (North Base). To the south, the Army Air Forces had already established a separate training base along the western lake shore for fighters and bombers (South Base). Before the end of 1942, North Base—known as the Muroc Flight Test Base—supported Army Air Forces tests of its first jet aircraft, the XP-59A. Tests for the XP-80, the first American production jet, soon followed. Work at the Muroc Flight Test Base continued after the end of World War II. North and South Base were distinct Army Air Forces installations of the war period, and today are subsumed within Edwards. Both bases were also known by several earlier names.[1]

Already characterized by a composite of military, civilians, and on-site contractors (Bell for the XP-59A and Lockheed for the XP-80), Muroc Flight Test Base (North Base) absorbed its sister Army Air Forces training installation of South Base as of late 1947—although the two sites remained discontiguous. Testing during the early Cold War years focused on unusual and experimental aircraft, and took advantage of clear skies, good weather, dry lake bed runways, and isolation for military development. Designated Edwards Air Force Base in December 1949, Muroc became the Air Force Flight Test Center under ARDC as of mid-1951. The Flight Test Center was one of 10 research, development, test and evaluation centers for the command by late in the decade. During the Cold War, Edwards was the site of continued aircraft flight testing, studies on horizontal sled tracks, a pilot school, aeromedical research, missiles and space vehicle test support, special weapons endeavors, and advanced propulsion development. The National Advisory Committee for Aeronautics (NACA), followed directly by its successor agency the National Aeronautics and Space Administration (NASA), also established itself as a major presence at Edwards during the years immediately after World War II. NASA developed its own clustered facilities on base, including a Space Shuttle maintenance and mating structure late in the Cold War. After the shuttle's successful landing on Rogers Dry Lake, personnel at this facility prepared the shuttle to return to the Kennedy Space Center in Florida on the back of a Boeing 747.

Primary Missions

The primary Cold War missions of ARDC / AFSC at Edwards Air Force Base included:

- initial flight testing for experimental and prototype aircraft;
- military aircraft flight testing;
- use tests of prototype hangars;
- multiple types of tests run on three sled tracks (two on base and one in Utah);
- the United States Air Force test pilot school;
- biochemical warfare testing;

- rocket motor and engine static testing;
- aeromedical research for high-altitude flight;
- chemical and physical laboratory analyses;
- tethered Minuteman I silo launches;
- development of heavy lift vehicles;
- satellite systems research, development, test, and evaluation;
- space technology programs;
- development of kinetic energy weapons for the Strategic Defense Initiative (SDI) [Star Wars];
- maintenance and flight of the airborne Argus testbed, focused on remote sensing studies, missile data analysis, and reentry vehicle tracking;
- solar energy rocket propulsion experimentation;
- testing of spacecraft and spacecraft components in simulated space environments and at very high altitudes; and,
- electric propulsion studies.

Edwards also hosted experimental reinforced concrete housing during the late 1940s—a period in which Headquarters United States Air Force looked at experimental housing for several of its installations, including Lustron all-steel houses with enamel paneling; aluminum, transportable houses; and, LeTourneau monolithic concrete houses (as at Edwards). Actual erection of concentrations of these unusual structures for military base housing was rare, but the testing of modern materials, in modular units, was a hallmark of ARDC / AFSC. The 100 LeTourneau houses at Edwards are very early and rare. The Air Force commissioned them for the installation in 1947. Also of major note, Edwards Air Force Base featured the world's longest runway as of 1954, at 15,000 feet.

Tenant Organization Missions

Edwards briefly hosted Air Defense Command (ADC) radar and fighter-interceptor squadrons on base, but otherwise did not support Air Force tenant missions. NACA and its follow-on agency NASA, however, was a major presence at the installation and remains so today. The civilian agency maintains its own distinct area and facilities. NACA / NASA missions at Edwards included:

- supersonic flight research;
- research on the X-series aircraft, including configuration explorers and unusually shaped planes, and rocket-powered supersonic aircraft launched from B-29s, B-50s, and B-52s;
- static testing of rocket motors and engines;
- hypersonic flight and space reentry research;
- tests run on Edward's high-speed sled tracks;
- development of lifting body programs;
- development and testing of the X-15;
- testing in simulated extreme high-heat environments;
- participation in research for Dyna-Soar (the X-20);
- Rogallo wing (Parawing) reentry studies;
- lunar landing research and test;
- research toward the space shuttle;
- integrated testing of aircraft systems;
- space shuttle landing;

- space shuttle maintenance and refitting; and,
- space shuttle mating for transport to the Kennedy Space Center.

Chronology

Edwards Air Force Base, first known as the Muroc Bombing and Gunnery Range, dates to 1940 as a formal military installation—although the Army had used the dry lake bed for training as of 1928. In 1933, Lieutenant Henry H. "Hap" Arnold made his initial visit to the site from March Field and began to take steps toward the establishment of a bombing and gunnery range. The two dry lakes of Rosamond and Rogers provided an attractive test setting for Army operations. Homesteaded and sparsely settled through the provisions of the Desert Land Act and railroad land grant sales, the area had a train station at Rodriguez (Muroc) by 1901. Desert homesteading of the Mojave, coupled with gold, silver, copper, borax, kernite, colemanite, ulexite, and clay mud mining, characterized the region even as the Air Force acquired its lands for Edwards into the middle 1950s. Reasonable proximity to Los Angeles also fostered movie making on site as well as automobile racing on the dry lake surfaces as of the early 1920s. Civilian aircraft manufacturers began testing planes on Rosamond and Rogers Dry Lakes by late in the decade, with the Army National Guard using the location for maneuvers. During World War II, the Army Air Forces erected a base of hangars and temporary buildings on the western edge of Rogers Dry Lake (South Base). The Army used the installation for fighter and bomber training throughout the war. Just as the war ended in 1945, the Army set up a B (bomber) -29 school for teaching radar bombing techniques.[2] The training installation featured 11 rammed-earth revetments. The Army Air Forces dispersed the revetments in a quantity-distance configuration appropriate to munitions-loaded aircraft. The unusual features sheltered nine bomber aircraft (B-24s) and two pursuit (fighter) aircraft (P-38s) as of 1942-1943. The revetments foreshadowed techniques used during the Vietnam War at bases in Southeast Asia to protect individual aircraft from counterinsurgency sabotage—where the successful explosion of one plane through a well-placed bomb could create a domino effect with its parked neighbors. The Vietnam revetments used prefabricated steel bins instead of rammed earth, and were an important project of AFSC (see Volume II, Chapter 4). The Army Air Forces had planned to erect 22 rammed-earth revetments at Edwards, also building at least some of these units at nearby Victorville Army Air Field (George Air Force Base).[3]

As of mid-1942, Army Air Forces Materiel Command at Wright Field in Dayton established the Materiel Center Command Flight Test Base at a separate site on the periphery of Rogers Dry Lake to the north of the training installation. Late the year before, Materiel Division (the predecessor of Materiel Command at Wright Field) had established a detachment at Muroc, with early tests of several remote-controlled weapons.[4] During the war, Army Air Forces Materiel Command renamed its flight test base Materiel Command Flight Test Base and then Muroc Flight Test Base. From the beginning, the test installation included representatives of private aircraft manufacturers. Northrop had its first flying wing, the N-1M, in test at Muroc at the close of 1941, while Curtiss-Wright used the dry lake beds for its CW-24B (a mock-up for its planned XP-55).[5] The command set up the Mojave Desert installation to test the Bell Aircraft XP (experimental pursuit) -59A jet fighter plane.[6] ("X" indicated experimental testing; "P," pursuit aircraft.[7] The Air Force changed its designation for fighter aircraft from "P" to "F" in July 1948.[8] "N" and "CW" are probably internal company references to Northrop and Curtiss-Wright, with "M" and "B" alpha-series designations assigned to the test aircraft.) Bell's aircraft plants were in upstate New York and Georgia, regionally near the Materiel Command depot bases of Griffiss and Robins. Lockheed (of Los Angeles) moved onto Muroc Flight Test Base to develop and test of the XP-80. From nearly the beginning, Muroc intertwined its mission with that of Palmdale Army Air Field. The base in Palmdale was located to the southwest of the flight test installation and today is the site of Air Force Plant 42 (see Volume II, Chapter 15). The 412[th] Fighter Group tested the XP-59A, the YP (prototype pursuit) -59A, and the

P-59A at Muroc Flight Test Base during 1944-1945. ("Y" indicated prototype testing.) Army Materiel Command physically stationed the P-59 aircraft at the Palmdale airfield, discussing placement of the 412th Fighter Group there as well. Pilots parked three XP-80 aircraft at the flight test base. While Lockheed manufactured these planes in one of its Los Angeles area plants, the company sought to build a flight testing and final assembly plant at the former Palmdale Army Air Field by 1949. Lockheed would participate in the operation of Air Force Plant 42 at Palmdale as of the early 1950s. The plant was a government-owned, contractor-operated (GOCO) facility. As of the main Cold War years, flight testing at Edwards and Air Force Plant 42 became thoroughly tied together—with photographs and tests at Palmdale sometimes cited as those of Edwards.[9] Other aircraft first flown at Muroc during 1943-1945 included the C (cargo) -69, XP-54, XP-56, XP-58, XP-81, and XP-79.

Also tested on site were three experimental "guided missiles": the MX (missile experiment) -334, MX-543, and MX-324. The MX-334 and MX-324 were actually Northrop unconventional aircraft. The MX-334 was the first American fully rocket-powered plane (the *Rocket Wing*), while the MX-324 was an aerodynamic test bed for a proposed fighter-interceptor.[10] MX-543 was another name for Northrop's JB (jet bomb)-1,[11] a jet-propelled, pilotless guided missile that the company developed for the Army Air Forces. The JB-1 was shaped as a flying wing (the *Bat*).[12] Northrop flight-tested the JB-1A at Muroc in December 1944.[13] The company additionally planned to test the JB-10 at the base late in World War II. Northrop designed the JB-10, another flying wing, pulsed-jet bomb, for launch from a track-based sled. The launch sled was to run along 300 feet of standard railroad track. To test the JB-10, Northrop built a six-foot wide, dual-rail launcher to the near northeast of Muroc Flight Test Base (North Base) in 1944.[14] While Northrop was developing the JB-10 as an improvement to the company's JB-1, the Army Air Forces abandoned continued work toward the weapon during 1945—although testing continued on the JB-10 into early 1946 when the Army Air Forces ended all JB production. Several sources indicate that Air Materiel Command planned to test Republic Aviation's JB-2 (MX-544) on the 2,000-foot sled track at Muroc (although the command never did so). Air Materiel Command did test the JB-1, JB-2 and JB-10 at the Santa Rosa Island launch complex erected for the JB-2 at Eglin Field in Florida. The Santa Rosa complex included a 50-foot inclined trailer ramp (autumn 1944), two three-degree, 350-foot steel-and-concrete-pier ramps (1945), and two portable launchers on concrete slabs (1945). After World War II, Air Materiel Command continued to test the JB-2 on a 400-foot inclined ramp at the Wendover Bombing Range in Utah. In late 1947, the command shifted the JB-2 test program to Holloman in New Mexico. The command shipped the Wendover launch track to Holloman for reerection there, with testing continuing into 1949. The JB-2 was the American version of the German V-1 (buzz bomb).[15]

Air Materiel Command modified the Northrop JB-10 launcher as a 2,000-foot deceleration sled track in 1946.[16] The track was one of a few such test facilities of the 1944-1946 period, with its original drawings dating to August 1944.[17] Sources debate the assignment of its operational capability, with some indicating that Northrop did not use the track until 1946. The Navy built another very early test track 60 miles to the north of Muroc during 1945-1946 at its China Lake installation to simulate missile acceleration, launch velocities, and burning in a scientific setting for ballistic and biological studies. The Navy track measured 1,500 feet. The China Lake track, not that at Muroc, may be the first missiles' components test track in actual operation.[18] (The only other similar test facilities were those for the JB-2 at Eglin and Wendover, and these were not true test tracks.) After the conclusion of the war in September 1945, the Muroc 2,000-foot test track became inactive until the Air Force adapted it for aeromedical testing. Dr. John Paul Stapp of the Aeromedical Laboratory at Wright Field conducted experiments to test new cockpit standards. His linear deceleration project of 1947, MX-981, tested human tolerance to gravitational forces. Project team members mounted an aircraft seat in multiple positions on the rocket sled to test abrupt acceleration and crash tolerance. Dr. Stapp

ran MX-981 for four years on the 2,000-foot test track. He used dummies, chimpanzees, and men (including himself) for the tests, assisted by Northrop crews. In late 1946, Northrop had added a hydro-braking system to the track, with the adaptation completed in April 1947. The first official Cold War test on the track was in December 1947, with Dr. Stapp as the first test subject. The Air Force added structures to the test complex during the next few years. Dr. Stapp also ran tests toward the development of the automobile seat belt in 1948, proposing the device in 1955. Northrop operated the 2,000-foot test track until July 1951.[19] By at least 1950, the track was alternately known as the Aero Medical Deceleration Test Facility.[20] ARDC dismantled the track in 1958.[21]

After World War II, Air Technical Service Command (the successor to Army Materiel Command late in the war) continued jet aircraft flight testing at Muroc. In October 1946, the command officially recognized what previously had been a classified operation. The Muroc Flight Test Base additionally hosted the Jet Propulsion Laboratory (JPL) of the California Institute of Technology in Pasadena. In 1940, Cal Tech had built its first static rocket engine test stands in the Arroyo Seco near its campus, but by 1945 had required a larger and more isolated site. The California Institute of Technology relocated its JPL facilities to Muroc at the near northwest of the Muroc Flight Test Base. (JPL's complex in the Arroyo Seco previously had been named the Guggenheim Aeronautical Laboratory, California Institute of Technology [GALCIT]. Between 1945 and 1951, the JPL area at Muroc was alternately known as the Ordnance Department, California Institute of Technology [ORDCIT] test station.) Static testing at Muroc went hand in hand with rocket and missile launches at White Sands Proving Ground in New Mexico. The Army tested versions of the Corporal rocket engine at the JPL's Muroc site. The initial static firing occurred in mid-September 1945. The facilities covered about 40 acres, with test personnel living at the remote station. The California Institute of Technology built its first rocket engine test stand, Test Stand A (alternately, the Corporal Test Stand), in early 1945. Tests continued without a break after the end of World War II. In 1946, JPL personnel fired scaled-down versions of the Corporal E on a vertical rail launcher on site. JPL successfully launched its first Corporal E in late May 1947 at White Sands.[22] At Muroc, the Air Force planned for rocket test stands on Leuhman Ridge to the southeast of Muroc Flight Test Base before the year closed. Representatives from the Power Plant Laboratory at Wright Field (see Volume II, Chapter 14) had selected the Leuhman Ridge as a follow-on to the Army Air Forces contract of 1946 with Consolidated-Vultee Aircraft Corporation to develop the Atlas intercontinental ballistic missile (ICBM) (see Volume II, Chapter 9).[23] Air Materiel Command selected Aerojet Engineering Corporation to build and run the Leuhman Ridge technical facilities.[24] As of early 1948, the Muroc Flight Test Base (North Base) expanded to include the former Army Air Forces training base on Rogers Dry Lake (South Base), with both installations designated Muroc Air Force Base (Plates 25-26). During 1946 and 1947, Muroc Flight Test Base had accommodated flight tests for 15 aircraft, for Republic, Douglas, Northrop, North American, Vought, Ryan, Lockheed, Bell, Convair, and Hughes. Army Air Forces and Air Force tests were in addition to JPL's rocket tests and the planning toward Leuhman Ridge.[25]

The group included experimental fighter and bomber aircraft, as well as work for the Navy and NACA. The X-1, the initial X-series aircraft, was among the earliest test flights. Pilots first flew Bell's X-1 in December 1946. The Air Force and NACA used the X-series aircraft to research the problems of transonic and supersonic flight. Engineers understood that near the speed of sound, jet aircraft encountered compressing shock waves. Bell powered the X-1 using a 6,000-pound thrust rocket that burned liquid oxygen (LOX) and a mixture of alcohol with distilled water. The Air Force, working with NACA, tested the X-1 by carrying the small plane to initial heights on the underside of a B-29, where the X-1 then continued its climb. In mid-October 1947, Air Force pilot Captain Charles E. "Chuck" Yeager became the first man to break the sound barrier, flying the X-1 at Muroc[26] (Plate 27). NACA formally arrived at the installation in September 1946, after the Army Air Forces had substantially discontinued use of its training base at Muroc (South Base). The small group of

Plate 25: Muroc Army Air Field (South Base). Aerial view, 10 October 1946. Courtesy of the History Office, Edwards Air Force Base.

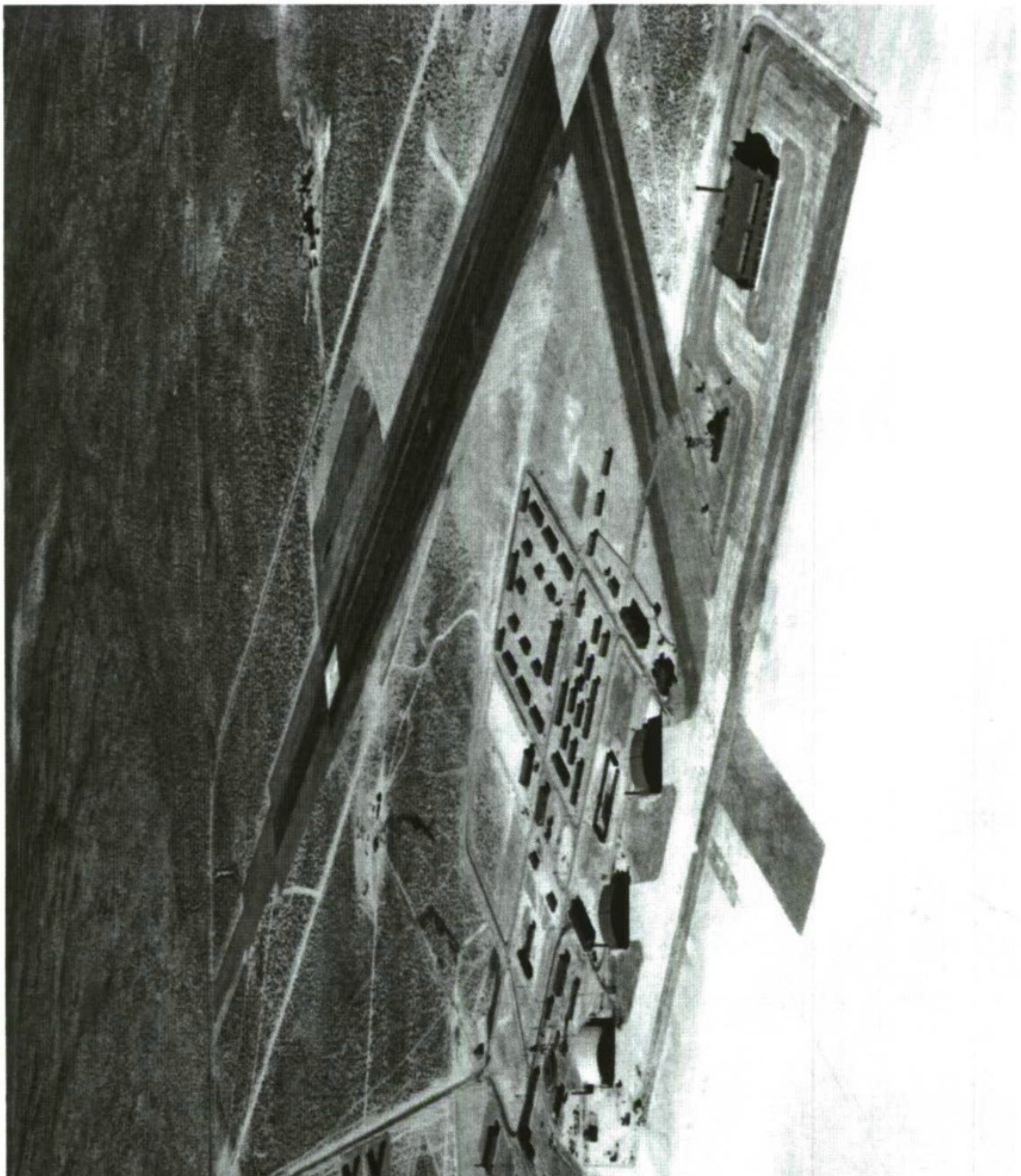

Plate 26: Muroc Flight Test Base (North Base). Aerial view, 10 October 1946. Courtesy of the History Office, Edwards Air Force Base.

men became the NACA Muroc Flight Test Unit, and adapted South Base for their facilities[27] (see Volume I, Part IV). Shortly after Yeager's record-setting flight in autumn 1947, an Air Force pilot also first flew Northrop's YB-49. Known as the Flying Wing, the YB-49 was not a successful aircraft but did contribute toward the ultimate development of Northrop's B-2 bomber of the post-Cold War years. The Air Force would rename Muroc Air Force Base as Edwards in recognition of Captain Glen W. Edwards. Captain Edwards had died test-flying the YB-49.[28] The YB-49 was also the aircraft that inspired the portrayal of Strategic Air Command's (SAC's) futuristic bombers in their fight against aliens in the 1952 Hollywood film *War of the Worlds* (Plate 28).

By early 1948, North Base (Muroc Air Force Base) and South Base (the NACA Muroc Flight Test Unit) continued to host flight test missions, as well as rocket and early missiles development. Both Headquarters Air Materiel Command and Headquarters NACA were firmly established at Wright-Patterson in Ohio and at Langley Air Force Base in Virginia, respectively, as major sites of aeronautical research and development (R&D). At this same time, Lockheed was positioning itself for an Air Force plant at nearby Palmdale. Actual facilities at what were coming to be known as North and South Base of Muroc Air Force Base were extremely minimal and largely temporary. NACA was dissatisfied with its allocated facilities on South Base, and the flight test center of Air Materiel Command on North Base was quickly outgrowing its early quarters. Master planning for an advanced installation began immediately. The first efforts toward the future base were those for family housing. Like the situation at Holloman in New Mexico, housing was a dire need. Unlike at Holloman, the Air Force, NACA, and aircraft contractors did not have a nearby town from which to base employees. In late 1942, the Army Air Forces had commissioned only a few single-family officers houses for Muroc Flight Test Base and Muroc Army Air Field. The cluster was the work of prominent Los Angeles architect H. Roy Kelley and is known as Area P. The Army erected the Area P cluster to the southwest of South Base.[29] At the outset of the Cold War, Air Materiel Command's developing flight test center required an immediate housing solution appropriate to the harsh extremes of the desert climate, post-World War II economies, and construction conditions of the remote site.

In 1946, Air Materiel Command initiated steps toward plans for Muroc Flight Test Base that would incorporate Rogers Dry Lake and test facilities on Leuhman Ridge. As of late January 1947, the War Department directed Muroc Army Air Field to proceed with a preliminary master plan, with submission to Headquarters Air Materiel Command and Headquarters Army Air Forces by May. The accepted plan created a new main base area centrally located between Muroc Flight Test Base (North Base) and Muroc Army Air Field (South Base). This "new base" was accessible to both the rocket motor test stands of the JPL and the Air Force (Plate 29). The Army proposed to dismantle much of the temporary infrastructure of World War II, with the exception of four hangars (including two Butler hangars), basic support facilities, runways and aprons, and the 10 Area P houses. Among the first tasks for the evolving new base was 100 units of family housing. Although Air Materiel Command and the Army Air Forces did not approve the master plan until late in May 1947,[30] specifications and drawings for the urgently needed houses were underway as of at least March. Similar to the Area P houses of 1942-1943, the houses of what would be called Area A featured a reinforced concrete structural system. The earlier Area P houses featured eight-inch-thick concrete block, reinforced with vertical steel bars.[31] The thick walls mimicked adobe construction in an attempt to create a static cooling system, although ordinary concrete often did not have good insulation qualities.

Air Materiel Command designated the 100 units of housing planned for Area A as "temporary," a term most accurately interpreted for Muroc as "transitional." The William Radkovich Company, Inc., of Los Angeles contracted for the Area A houses.[32] Radkovich erected precast reinforced concrete LeTourneau houses patented by the LeTourneau Company of Longview, Texas. The houses (predominantly, Buildings 5002-5099) occupied seven curvilinear clusters that each faced an

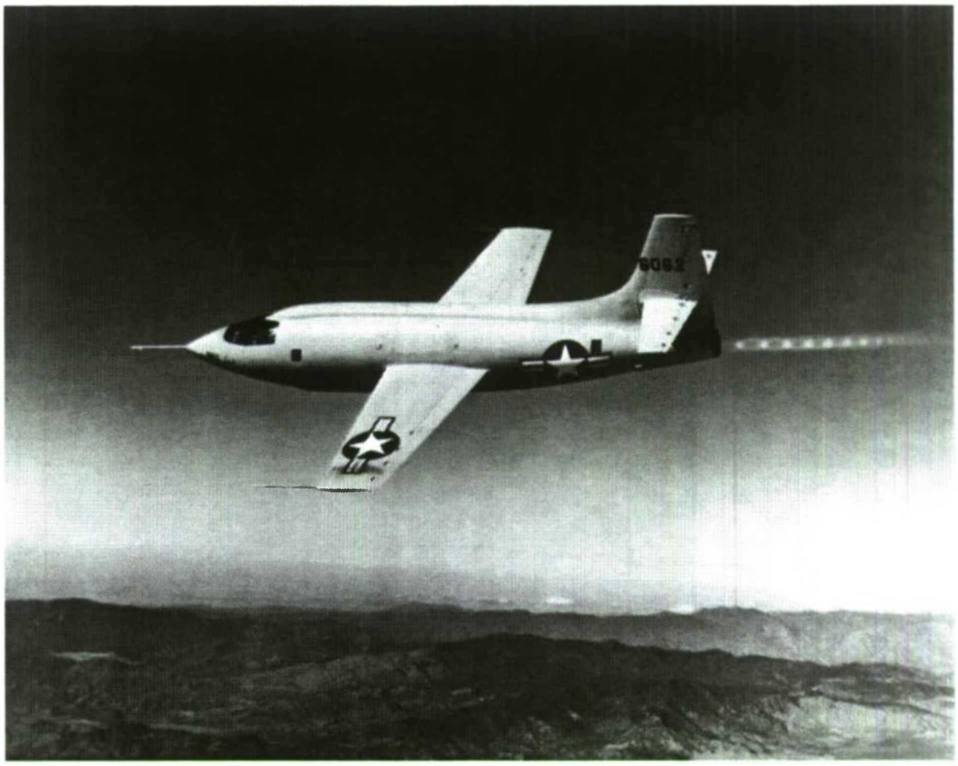

Plate 27: Captain Charles E. "Chuck" Yeager Flying the X-1, 14 October 1947. Courtesy of the History Office, Edwards Air Force Base.

Plate 28: Test Flight of the YB-49 at Muroc Flight Test Base, late 1947. In *History of the Air Materiel Command 1948.*

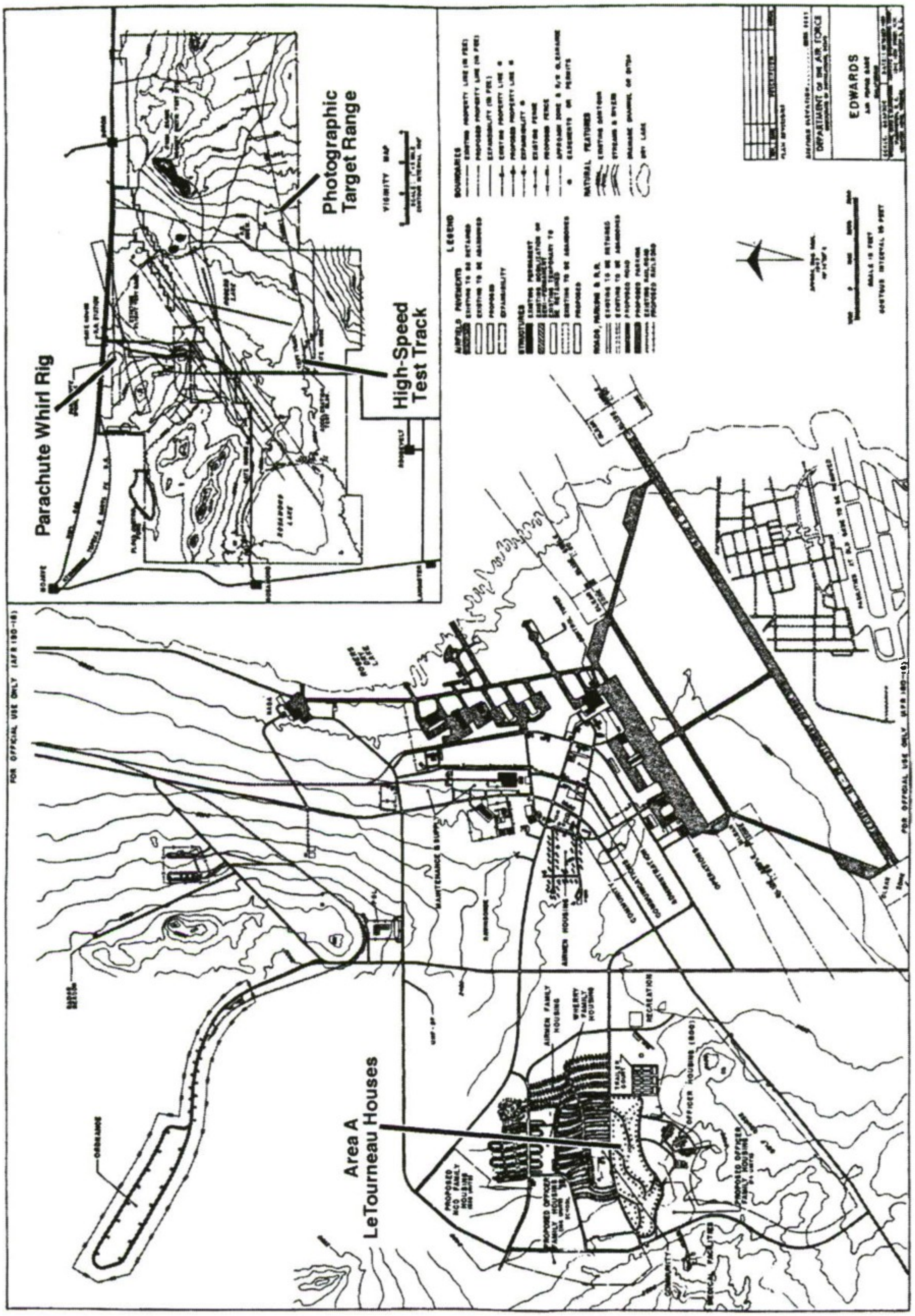

Plate 29: Directorate of Installations, Headquarters United States Air Force. Master Plan for Edwards Air Force Base, October 1957. Annotations added. Collection of K.J. Weitze.

unfenced communal rear recreation area (see Plate 29). The LeTourneau house featured two prefabricated units: an 18- by 24-foot living room and the 32-foot, 8-inch by 24-foot section containing the kitchen, service porch, bathroom, linen storage, and two bedrooms. A conventionally built, 18- by 7-foot entry hall and open-plan dining room connected the units. The LeTourneau house was a concrete box, with below-ground piers, a concrete-slab floor, reinforced concrete walls, and eight-inch-thick flat reinforced concrete roofs.[33] Local contractors, or "designers," leased LeTourneau equipment for the houses, purchased the materials, and configured the two components of the individual houses to create the finished product—which could vary in footprint, size, elevation, and finish. At Muroc, the first pour for the Area A houses occurred on 2 October 1947.[34] The technology for the LeTourneau house was notable and experimental, economic and fast.[35] The pumice aggregate mixed with traditional cement made for a lighter, thick-walled structure, and one that offered insulation from the extremes of heat and cold (although the Edwards houses did have air conditioning).[36] LeTourneau designed the concrete mix in this manner specifically to prevent sweating or moisture condensation, as well as to maximize insulation and economize construction.[37] The first model LeTourneau house cost $3,500 in 1946. The improved model at Edwards of 1947 was more than twice as expensive, at $7,500.[38] Edwards modified its LeTourneau houses in the early 1970s through the addition of concrete-block garages and rear concrete-block walls (to enclose a small yard).[39] The base also carried out a major facelift late in the Cold War, adding gabled roofs.[40]

By early 1948, the newly independent Air Force was seriously evaluating the purchase of prefabricated structures for a number of its installations where housing was a critical issue. The choice of the LeTourneau precast concrete house for Muroc in spring 1947 is very early, and may be the first such operational choice for the Army Air Forces / Air Force anywhere. Throughout World War II, Air Materiel Command had consistently sponsored evaluations of prefabricated structures, including personnel shelters, hangars, engine docks, and maintenance stands. Selection of LeTourneau houses for Muroc is consistent with the goals of the command. Not until 1948-1949, however, did the Air Force and other military service arms begin to erect units of prefabricated housing at its installations[41] By this date, the 100 LeTourneau precast concrete houses were nearing completion at Edwards Air Force Base (Plate 30). Erected nearly simultaneously with the Edwards group were small clusters of LeTourneau houses in Los Angeles and Corpus Christi, Texas. Other locations for LeTourneau houses included Inyokern, California; Yuma, Arizona; and, Longview, Texas. William Radkovich and James Y. Orms handled all of the Southern California and South Texas jobs, respectively. The two men may well represent the extent of the LeTourneau house phenomenon. LeTourneau houses for Inyokern and Yuma were probably Navy and Marine Corps facilities, constructed at these isolated desert installations for reasons very similar to those mandating the housing choice at Edwards. The LeTourneau houses for Yuma were identical to the houses erected for Edwards.[42] During 1949, the Air Force and the Marines commissioned other notable clusters of prefabricated housing at installations in the United States. These included at least 61 Lustron houses for officers' families at Quantico, Virginia (Marines),[43] and plans for 70 Lustron units or "Southern California Homes (aluminum)" at Scott Air Force Base in Illinois.[44] LeTourneau, and most of his competitors, stopped manufacturing houses in about 1950. Many reasons surfaced for prefabricated military housing during the first years of the Cold War. In another example, SAC's commander General Curtis E. LeMay wanted fireproof construction, a modern image, and economy. By 1951, SAC elected to build all-steel elite airmen dormitories. The Detroit Steel Products Company manufactured the dormitories, with clusters of the housing at selected SAC installations of 1952-1954.[45] SAC's steel dormitories concluded the phenomenon begun with LeTourneau houses in 1947.

As of mid-February 1948, the former Muroc Flight Test Base and the Muroc Army Air Field officially became Muroc Air Force Base under Air Materiel Command. In early December 1949, the command renamed the base Edwards. The installation's primary mission continued to be flight

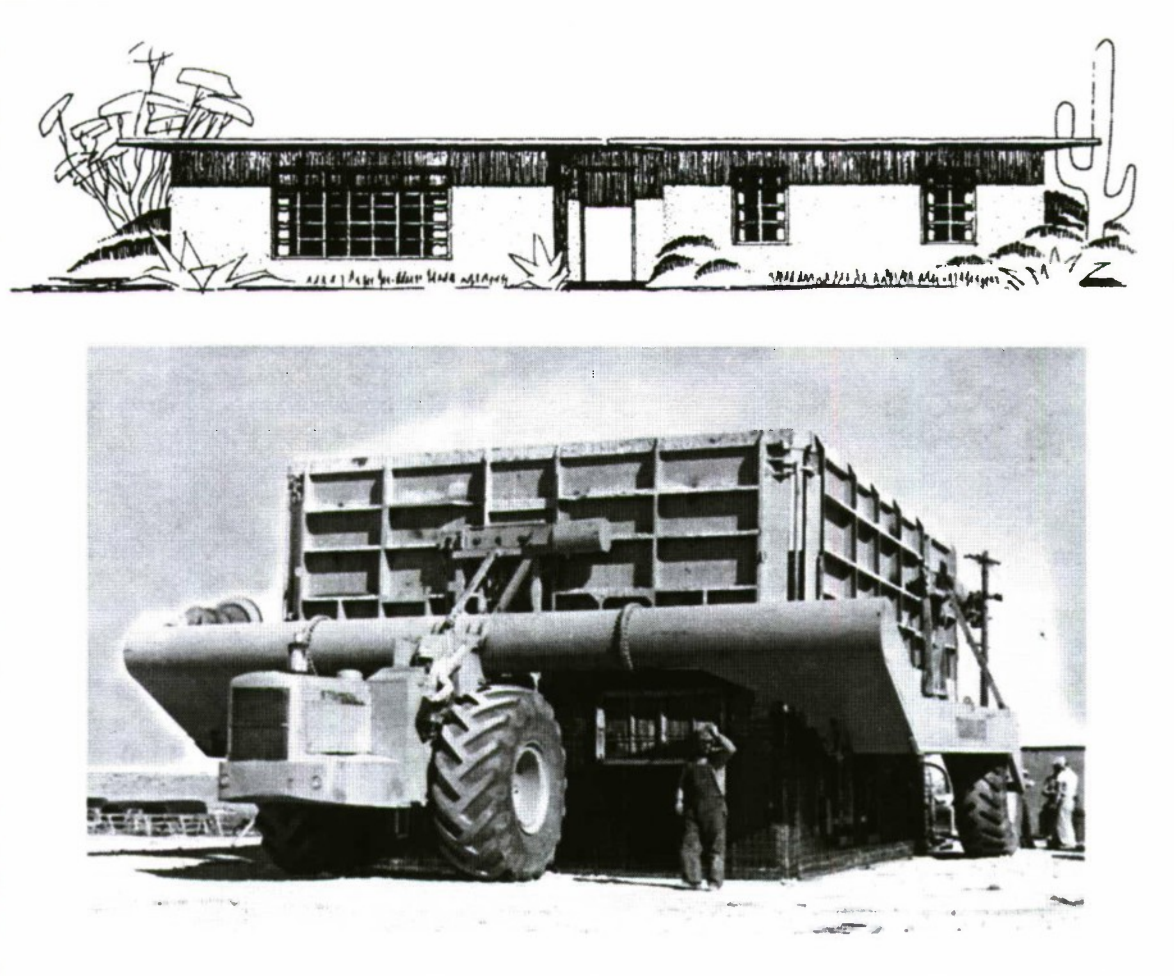

Plate 30: William Radkovich Company. LeTourneau House, Area A, Muroc Army Air Field / Air Force Base (Edwards), 1947-1948. Elevation drawing in R.G. LeTourneau, Inc., *Low Cost Housing by the Houselayer Form System*, ca.1949-1950. Photograph showing a Tournalayer placing the outer house form over the prepared inner house form, 15 February 1948. Courtesy of the LeTourneau Archives, Longview, Texas.

testing. In June 1951, ARDC designated Edwards the Air Force Flight Test Center. During the 1948-1951 period, pilots and engineers at Muroc / Edwards flight-tested 18 aircraft for Douglas, Curtiss, Northrop, McDonnell, Convair, Lockheed, Republic, North American, and Bell. Included within the early Cold War group were the experimental F-89 Scorpion (the XF-89), the jet fighter that would first carry the nuclear-tipped MB-1 Genie air-to-air guided missile as of 1957; the YF-86D, the workhorse fighter of the Korean War and of fighter-interceptor squadrons assigned air defense missions in the United States through the middle 1950s; several Navy aircraft; and, a continuation of the X-series research planes.[46] As the base began to settle into its role as a Cold War flight test center, the Air Force transferred the Air Materiel Command Experimental Test Pilot School from Wright-Patterson to Edwards. The school became an ARDC facility shortly after its placement in California and grew during the 1950s and 1960s to an Air Force-wide institution that included aerospace training. After the Apollo 11 mission, the school shifted away from a space mission, thereafter again focused on flight testing and aircraft appraisal.[47]

Test facilities at the base during the late 1940s also included a second 10,000-foot test track, under construction as of 1948. The Edwards test track had ties to tracks in planning and development at several other military installations. In 1946-1947, the Navy had built a mile-long moving target track at China Lake and had expanded the test facility to 14,000 feet in 1947 as the Baker 4 (B-4) track. The Navy's Baker 4 track was of light construction, but did include captive-flight testing.[48] Air Materiel Command planned a 10,000-foot high-speed test track at either Holloman or Edwards Air Force Bases as of October 1948, with the intention of having the track serve as a captive-test facility and as a rail launcher for the Falcon and Snark guided missiles (Hughes and Northrop). Hughes very quickly built its own rail launcher at Holloman, physically attached to the JB-2 ramp at the installation. Northrop took the lead as designer of the required high-speed test track, with the focus shifted to testing for Snark. While planning went forward for the Air Materiel Command test track, the first choice for its physical siting was at Holloman. Before construction, however, the command revised its selection to Edwards, citing the lower elevation of the Mojave Desert location and the proximity to the Southern California contractors. One particular attribute of the lower elevation at Edwards was its allowance for higher Reynolds numbers. As mathematical correction factors, Reynolds numbers permitted scientists and engineers to project their findings from scale models to full-sized vehicles. With the move to Edwards, the track became a multipurpose, transonic aerodynamic test facility. Northrop constructed a shorter, heavier track of 3,500 feet at Holloman in 1949 to serve as the rail launcher for Snark.[49]

Northrop built the 10,000-foot high-speed track at Edwards, first known as the Free Air Test Facility, during 1948-1949 under its contract for the Snark guided missile (Plate 31). During 1950, after inspection trips to both the "research tracks of Holloman AFB and the Inyokern Test Station [China Lake]," Air Materiel Command added a block house with a "remote viewing system," observation stations at the center of the track and at the water brake end, communications and instrumentation systems, additional water supply, and an electrical distribution system.[50] The track accommodated tests for pilot ejection, parachute recovery, and human tolerances (as had been true on the 2,000-foot track). The high-speed test tracks at Holloman, China Lake (Navy), and Edwards continued to affect one another during the 1950s as they leap-frogged in test lengths. The Navy conducted Project Supersonic Naval Ordnance Research Track (SNORT) tests on the Edwards 10,000-foot track during 1951-1953 to compare accelerations, rail deflections, foundation vibration, and water brake data between the Edwards track and the existing 14,000-foot Navy B-4 track. Subsequently, the Navy built its 21,000-foot SNORT track at China Lake.[51] In late 1958, ARDC renovated the 10,000-foot test facility at Edwards. The command replaced the track in two 10,000-foot segments between 1957 and 1959. The original underground control center (blockhouse) for the 10,000-foot track of 1948-1950, sited at its beginning, became a half-way point (as an electronic data relay station) between the 10,000 feet of new track laid during 1957-1958 and the 10,000 feet laid in the bed of demolished track during 1958-1959. The length of the late 1950s track increased the speeds at which tests could run, from Mach 2 to Mach 4.[52] In 1963, AFSC dismantled the 20,000-foot Edwards track, with the Air Force thereafter concentrating its track testing at Holloman—where the Air Force had lengthened the original High Speed Test Track from 3,500 feet to 5,021 feet in 1952, and to 35,000 feet in 1957[53] (Plate 32).

Other important improvements and new missions at the outset of the 1950s included continued construction of the technical facilities for the rocket test station on Leuhman Ridge (the Experimental Rocket Engine Test Station) and at the JPL site near North Base. Two static test stands, 1-3A and 1-5A, were operational on Leuhman Ridge in 1953—with a first hot run in July 1952 (see Plate 41). Each of the test stands featured a flame bucket, with washdown nozzles using 4,000 gallons of water per minute to flush corrosive fuels down trenches into the valley. The deluge system was identical to that for Atlas launch stands later in the decade at Vandenberg Air Force Base on the Southern California coast. In late 1953, one method of observing tests included an unmanned M-5 tank, placed

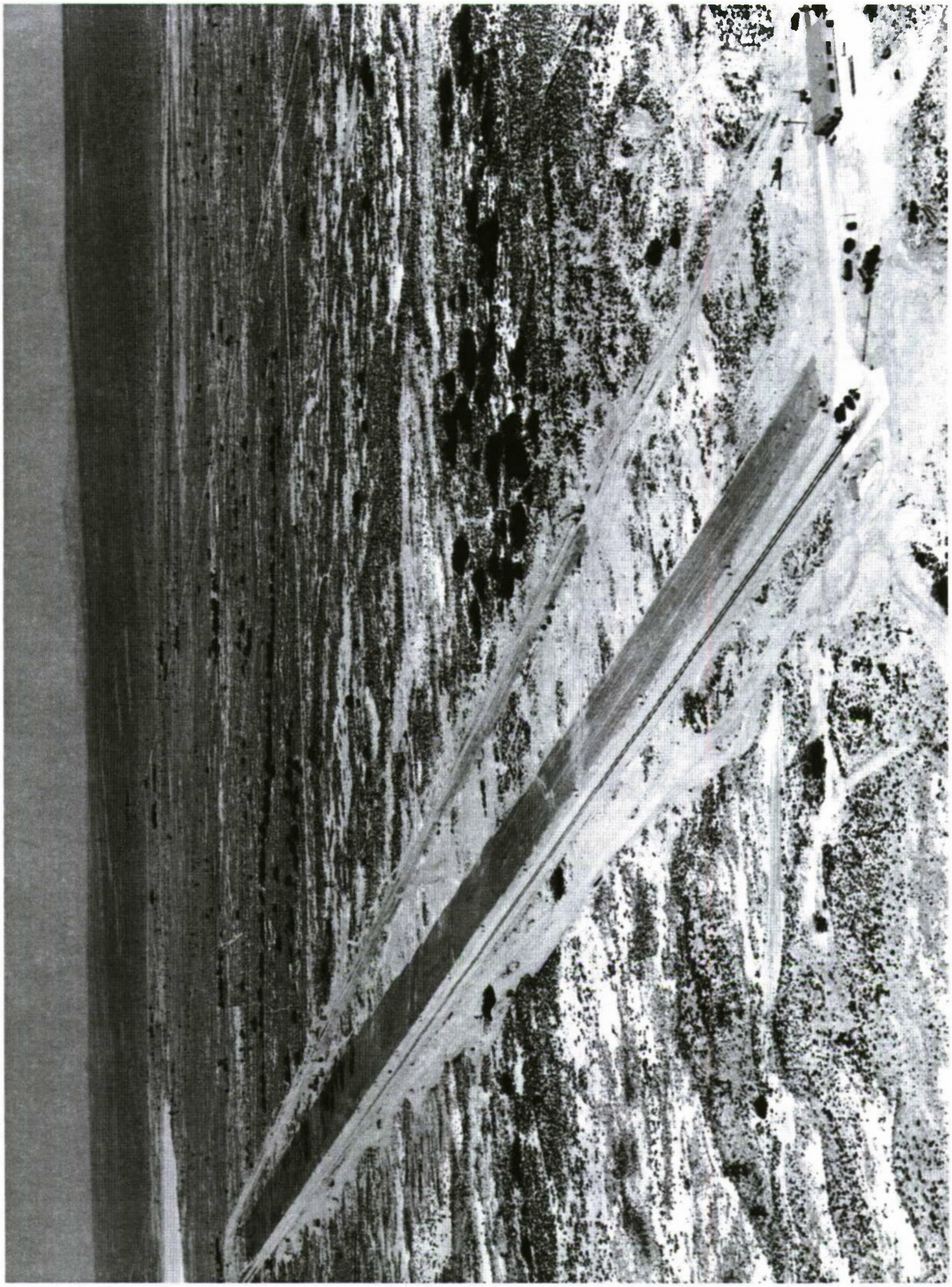

Plate 31: 10,000-Foot High-Speed Test Track, Air Force Flight Test Center, Edwards Air Force Base, ca.1950. Courtesy of the History Office, Edwards Air Force Base.

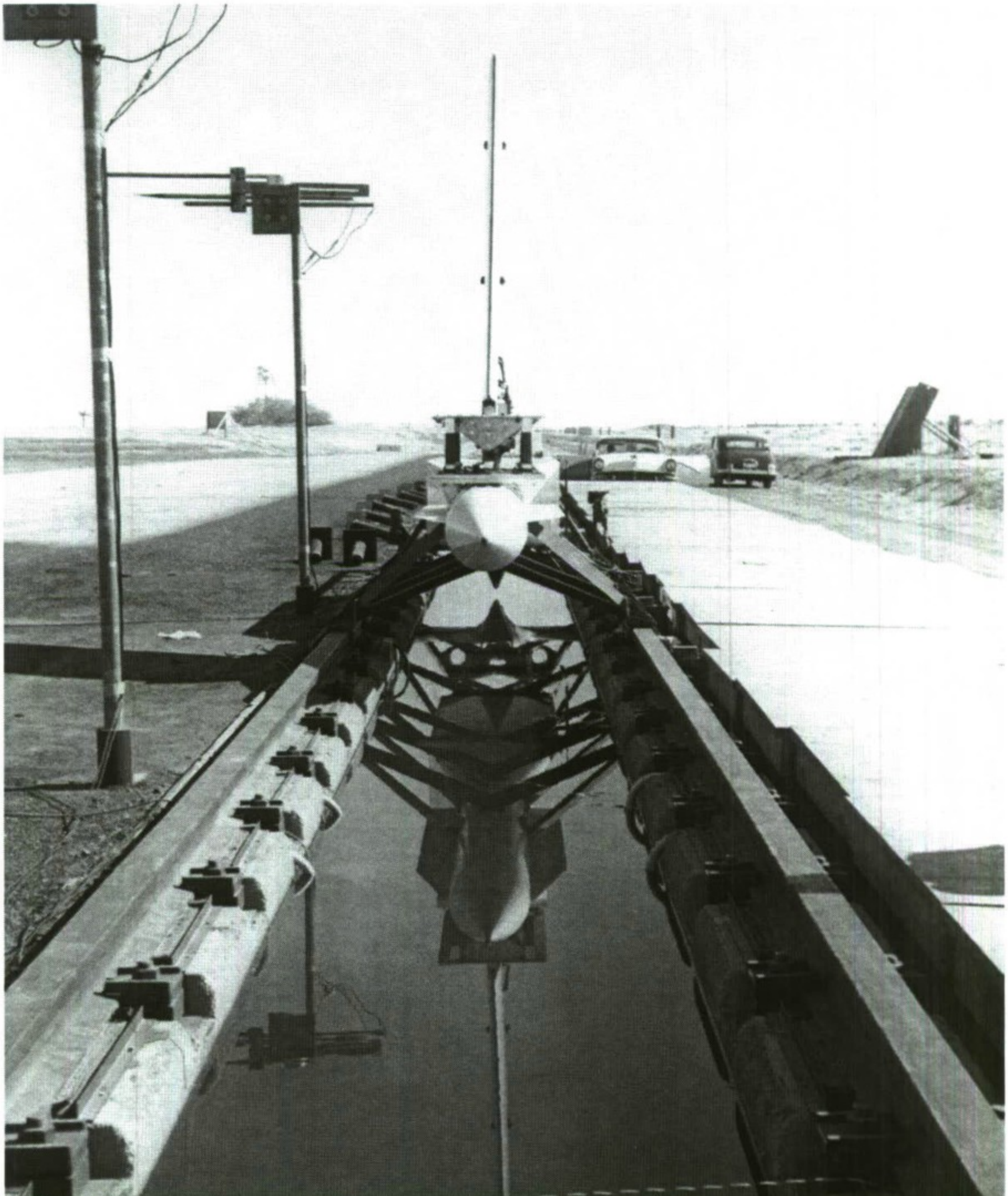

Plate 32: 20,000-Foot High-Speed Test Track, Air Force Flight Test Center, Edwards Air Force Base, 19 October 1960. Blast effects in airfoils, static run 5. Courtesy of the History Office, Edwards Air Force Base.

on the valley floor with recording equipment and moved slowly toward the test stands. The turretless tank, painted yellow, could withstand temperatures of 500 degrees Fahrenheit.[54] First tests included ones toward ICBM development, using captured German V-2 rockets. Motors for Bomarc and Navaho missiles were also in test as of 1953. During 1954-1955, ARDC added test stands 1-3B, 1-5B, 1-5C, 1-4, and 1-21. Ralph M. Parsons designed the rocket test station, working with Aerojet Engineering.[55] Both firms had their main offices in Los Angeles. Parsons rose as a prominent engineering company after World War II. The firm undertook many assignments tied to the special infrastructure required for missiles development and operational launch, both for the Air Force and the Army. The major early test stands and blockhouses at the Redstone Arsenal in Huntsville, Alabama, for example, are the work of Ralph M. Parsons, and are of simultaneous execution with the first test stands on Leuhman Ridge. At some date, Ralph M. Parsons became formally affiliated with Aerojet as Aerojet-Parsons for selected commissions.[56] Aerojet Engineering designated the initial support areas for the rocket test center as 2-10 and 2-20, with a "1" prefix indicating high hazard and a "2" indicating minimal hazard.[57] During the 1950s, missiles in static test on these stands included the Bomarc, Navaho, Showboat (a research engine), Thor, Atlas, and Titan—with development of the Bomarc, Navaho, and Atlas first in the group. The Air Force also tested the X-15 engine on Test Stand 1-21.[58] As of 1954, contractors working at Leuhman Ridge also coordinated closely with the Western Development Division (WDD) of ARDC in Los Angeles. The WDD would evolve into the Air Force Ballistic Missile Division (AFBMD) of the command, and with subsequent name changes would direct development of both ICBMs and selected space systems (see Volume II, Chapter 9). Simultaneously during the early 1950s, JPL initiated a shift in its R&D efforts from guided missiles to space exploration. In 1953, JPL built a second rocket engine test stand, Test Stand B, at its Edwards complex. Test Stand B was known as Short Snorter and was small. Short Snorter tested engines horizontally over a shallow concrete-lined trench and vented exhaust directly into the atmosphere. A small cluster of support buildings accompanied the test stand, as had been true for Test Stand A in the middle 1940s. In 1954, JPL began to work on Project Orbiter, a satellite developmental mission that used Sergeant motors as boosters.[59] (JPL had followed its work on the Corporal with work on Sergeant, although testing for the Sergeant occurred at the JPL facilities in Pasadena.)

Facilities and mission development at Edwards were still in transition during the early 1950s. Selected missions and their associated infrastructure were at the installation only briefly, thereafter established permanently at off-site locations. Between 1952 and 1954, the Air Force Flight Test Center also benefited from the loan of three German engineers working through Project Paperclip at Wright-Patterson. Dr. Hans J. Pabst von Ohain, a renowned jet engine specialist, was on temporary duty assignment to Edwards several times between 1948 and 1954. Wilhelm Buss, a parachute designer for the Luftwaffe during World War II, was at Edwards as a Project 63 hire. Dr. Theodor Knacke, long-term at Wright-Patterson, worked at the parachute test facility at El Centro, an off-site test installation subsumed under Edwards' jurisdiction (see Volume I, Part III). As of 1950, Air Materiel Command was erecting a "large whirl rig and compressed air cannon" at Edwards to test experimental parachutes "at extremely high velocities in the horizontal plane by accelerating a body and releasing it with the parachute attached."[60] The whirl rig test location was due west of the JPL test station, mapped through 1957 but gone by 1959 (see Plate 29). In addition to the parachute test facilities at Edwards, ARDC managed the Joint Parachute Test Facility with the Navy at El Centro. ARDC participation in the Joint Parachute Test Facility dated to spring 1951 through placement of the 2752nd Experimental Group there (followed by the 6511th Parachute Development Test Group by 1953) (see Volume I, Part II). The El Centro test station handled personnel and heavy cargo drops, as well as munitions drops—with drops over a 40-acre land area and over the nearby Salton Sea, an inland body of water. The Wright Air Development Center managed the ARDC projects at El Centro, and also took charge of Army efforts on site. (The Navy had responsibility for Marine projects at El Centro.)[61] In early 1955, the 6511th Parachute Development Test Group conducted projects at El Centro for the Matador and Bomarc guided missiles (parachute recovery tests), and for

the unresearched weapons systems of MX-2013, MX-2144, and MX-2224. A parachute whirl rig became operational at the El Centro facility as of April, with shakedown tests through July. The El Centro whirl rig likely replaced the rig at Edwards.[62]

Other Edwards missions and associated test infrastructure of the early 1950s included an aerial photographic target range, biochemical weapons test responsibilities, a launch site for Moby Dick and possibly for Gopher, and the 750th Aircraft Control & Warning (AC&W) Squadron. The photographic target range consisted of 34 "photographic patterns constructed from Concrete and painted in various colors," designed to provide photographic resolution data. Targets ranged from ones of 500 square feet, to others of more than 57,000 square feet. Edwards personnel erected the 34 targets along a 20-mile length, approximately 5,000 feet apart. The targets helped ARDC evaluate developmental equipment tested at extreme operating altitudes.[63] The photographic target range paralleled the 10,000-foot high-speed test track, and extended to the east (see Plate 29). For a few years between 1951 and mid-decade, Edwards was also one of three ARDC installations assigned a role in the command's efforts toward the development of biochemical weapons. The Armament Test Division at Eglin was the primary responsible unit, with Edwards the location for tests of high-speed biochemical bomblet clusters. AFSC, the follow-on to ARDC, mapped a parachute drop zone over the Rosamond Dry Lake area through at least 1963.[64] Holloman was the command's site for dispersion and fuze functioning tests for biological weapons, as well as for tests of chemical warheads adapted to guided missiles (see Volume I, Part III). Additional biochemical work accrued to Edwards through project Moby Dick, and possibly Gopher. Both Moby Dick and Gopher were high-altitude balloon tests of the upper atmosphere. The Cambridge Research Center (Laboratories) at Hanscom Air Force Base near Boston predominantly ran these tests. Moby Dick studied high-altitude wind fields, with prototype launches and crew training at Holloman. The program included three operational West Coast launch sites. Two launch stations were in California, one affiliated with Edwards and one in the San Joaquin Valley. The third station was at a Navy installation in Oregon. By 1953, the Air Force planned two more Moby Dick launch sites for Georgia and Missouri. Both overlapping and continuing Moby Dick was Gopher, a balloon launch operation configured exactly as for Moby Dick and one that supported a biological munitions package. Yet a third study using the same five-launch site plan supported an anti-crop bomb lifted by balloon, with the live agent stored at the Ogden Air Materiel Area (see Volume II, Chapter 6). ARDC cancelled the projects in 1955, after six years of work (see Volume I, Part III).

Two short tenant missions at Edwards were an air defense radar station at the outset of the 1950s, followed a decade later by an alert fighter-interceptor squadron (FIS). The first facilities for the 750th AC&W were temporary buildings at Edwards, as of late 1950 (Plate 33). The squadron moved to permanent Type I and Type II Operations Buildings at Boron (Atolia) as of January 1952 and thereafter became an affiliated off-site responsibility for the base (see Volume I, Part IV). The Boron AC&W radar station continued as an ADC tenant attached to Edwards into the 1960s. In 1961, Headquarters ADC planned to augment its fighter-interceptor alert capabilities in Southern California through redeployment of the 15th FIS from Davis-Monthan Air Force Base in Tucson to either Oxnard, Edwards, George, or March Air Force Bases.[65] Geographic assignment was only one aspect of ADC's concern for FIS alert stagings. At Davis-Monthan, Oxnard, and George, the command had quartered FIS in Butler alert hangars, facilities typically in place at the very beginnings of alert in 1951-1952, or in remote areas requiring immediate, economical infrastructure. Neither Edwards nor March had existing FIS alert facilities in 1961 (apron, alert hangar, ready crew dormitory, maintenance hangars, flight simulator, operations building, armament-electronics shop, weapons calibration shelter, and weapons storage). While Oxnard had a particularly complete group of support structures for its ADC alert area with a FIS in place, its runway was only 8,000 long and base family housing was minimal. (Oxnard Air Force Base, south of Santa Barbara, would close in 1969.) George, to the southeast of Edwards, featured a 12,000-foot long runway, with a reasonably good

Plate 33: Interior of the Transmitter Building (Jamesway Hutment), 750th Aircraft Control & Warning Squadron, Edwards Air Force Base, 1951. In Air Defense Command, *History of the 27th Air Division (Defense) 1 April – 30 June 1951* [Norton Air Force Base].

complement of existing ADC alert support infrastructure. March, near Riverside, had an excellent runway 13,300 feet long and 200 feet wide, but no ADC infrastructure of any kind.[66] Edwards, with its 15,000- by 300-foot runway and its two resited World War II hangars near the end of its flightline (Buildings 1207 and 1210) offered the solution that ADC desired. The command felt that an alert FIS at Edwards could use Building 1210 as the "basis for the Ready Crew, Flight Simulator Training Building and Armament and Electronics Shop." ADC further indicated that the command did not want two FIS on a single installation (eliminating Oxnard); that March had a "climb corridor and air space problem as well as vulnerability;" and, that "George has excessive costs and is already saturated."[67] As of March 1963, ADC had a FIS on alert at Edwards, although the command did not move the 15th FIS from Davis-Monthan but instead set up a detachment of the 329th FIS from nearby George. Between early 1963 and July 1967, Detachment 1 of the 329th FIS positioned four F-106s on alert along a taxiway at Edwards for coverage requirements of the Los Angeles Air Defense Sector (see Volume I, Part III). Support facilities were minimal and included an existing ready crew dormitory near the flightline (Building 1250), but no alert apron or hangar.[68]

By the middle 1950s, plans toward consolidation of North and South Bases, centered on the development of a new site between the two World War II facilities, were well underway and brought significant new infrastructure to the Air Force Flight Test Center.[69] Air Materiel Command retained J. Gordon Turnbull of Cleveland during 1949-1950 to evaluate the 1947 master plan. Turnbull's firm was simultaneously working on an underground pilot plant project for the command, based on protective German construction of World War II (see Volume I, Part III). By late 1951, planning went forward through the Los Angeles firm of Pereira & Luckman. The firm drafted a new master plan based on Turnbull's review. In the same year, Edwards expanded its family residence area with 724 units of Wherry housing.[70] The Wherry cluster abutted the 100 LeTourneau houses of 1947 (see Plate 29). The focalpiece of the new Air Force Flight Test Center, however, was its proposed

runway. Engineers designed the 15,000-foot runway to handle 500,000 pounds of aircraft weight. The runway featured a reinforced concrete bed, 17 to 19 inches thick.[71] Under construction throughout 1954, the runway was the longest in the world at the time, made longer through the abutment of one end against Rogers Dry Lake. Dry 10 months out of 12, the rock-hard, level lake bed created a usable extension of the paved runway to 16,800 feet.[72] By this date, the B-36—a bomber weighing between 265,000 and 300,000 pounds in its developed versions—had stimulated engineers to design heavy runways 11,000 to 13,000 feet long and 300 feet wide. The earliest B-36 runways dated to 1945 (at Carswell Air Force Base in Fort Worth to accommodate production of the bomber at Air Force Plant 4 and at Eglin for the bomber's armament testing.) SAC's first runways for the operational B-36 were at Ellsworth and Loring Air Force Bases, in South Dakota and Maine respectively. The Air Force built these two important runways during 1948-1949. Other installations, especially selected depot bases of Air Materiel Command, also handled the B-36 in limited ways, although typically did not add new runways for the bomber until 1953-1954 (such as at Kelly Air Force Base in San Antonio). Wright-Patterson functioned much like one of these installations, B-36-capable but not for an extended period.

Engineers for the runway at the Air Force Flight Test Center certainly used the known parameters of the B-36 as the benchmark for its design, as well as for the initial choice of a Cold War maintenance hangar at the base, although the center did not test the experimental and developmental models of the bomber. In November 1954, the runway opened for flight test operations of the B-52, the next generation of heavy bomber for SAC. (The YB-52 had arrived at Edwards in June 1953.[73]) Through about 1956-1957, pilots also landed the B-36 at Edwards, which implies some level of late test operations. The runway could easily accommodate both aircraft. At Edwards, ARDC planned to handle "the largest transport, bomber, or cargo aircraft presently in use, or contemplated."

> This runway...must not be considered as a prototype for other Air Force runways, for it will be used for the testing of experimental aircraft and forthcoming production models. These aircraft, with their increased speeds and weights, require a longer, smoother, and stronger runway than any previously used until the tests are past the critical stage.[74]

The large maintenance hangar, Building 1414, was one of 53 to 55 identical double-cantilever hangars built in the continental United States and at selected overseas sites. Specifically designed and engineered for the B-36, the double-cantilever hangar (also known as a DC hangar) was the design of Kuljian Corporation of Philadelphia. Dating to autumn 1951, design and engineering for the hangar was an accelerated program to handle maintenance of the very large B-36, with its wingspan of 236 feet. Interior clearspan, as well as sufficient center height (to allow the tail of the bomber), was critical. Cantilevering of this period did not accommodate the necessary clearspan, although a few existing arch designs had achieved the requisite open space. Primarily needed at bases where SAC stationed the B-36, the double-cantilever hangar was also expansible. This feature of the hangar had been a design requirement, so that the building could shelter either more aircraft at an installation or even larger aircraft in the future. The earliest, full-scale B-36 hangar had been a nonexpansible, thin-shell reinforced concrete arch structure (built twice, at Ellsworth and Loring), designed in mid-1947. The entire engineering problem set dated back to 1944, with a spaceframe, double-cantilever hangar patented by Konrad Wachsmann and Paul Weidlinger. Air Materiel Command at Wright-Patterson contracted with Wachsmann again in 1952-1954 to rework his futuristic World War II design, although still without fulfilling the promise of the first idea (see Volume I, Parts III and IV).

Kuljian designed the double-cantilever hangar in three sizes: a 250- by 250-foot basic hangar (as at Edwards), a 350- by 250-foot two-bay (or medium) hangar, and a 600- by 250-foot three-bay (or

large) hangar. Air Force construction of its 50+ double-cantilever hangars occurred between 1951 and 1957, and was a very important agencywide program. All of the hangars relied on the 1951 design, even when actual erection was at a later date. The hangar at Edwards was under construction during 1955-1956 (Plate 34). (Completion of the double-cantilever hangar typically occupied two full years.) The double-cantilever hangar, with 60 feet of height clearance, allowed the B-36 (or other large aircraft) to pull in from both sides, with either a portion of the nose or tail of the aircraft remaining outside the hangar. The largest of the double-cantilever hangars, built only rarely, allowed work on six B-36s at one time.[75] The Army Corps of Engineers typically sent the standardized drawings for the double-cantilever hangar to its regional offices, where in a number of instances the architectural-engineering firm hired to manage construction and make any site adaptations (such as foundation work) would insert its name into the title block. Such was the case at Edwards, which has obscured the hangar's link to the double-cantilever program. The double-cantilever hangar has had a long and productive life for the Air Force, and is still actively used on operational bases. The hangar served the B-36, B-47, and B-52 at many SAC installations. Building 1414 at Edwards first accommodated the B-52. During the middle 1960s into the early 1970s, AFSC and NASA personnel used the hangar for maintenance and test of the SR-71 spy reconnaissance plane. (Lockheed developed and manufactured the SR-71, with the contractor's operations part of Air Force Plant 42 in nearby Palmdale.) Next NASA and Lockheed retooled Building 1414 for the YF-12A until mid-decade, when the Airborne Warning and Control System (AWACS) Test Force occupied the hangar until the Air Force made a production decision for the airborne radar aircraft in 1974. Other aircraft followed.[76]

Predictably, the flight test mission at Edwards required multiple large and unusual hangars. This situation sometimes led to the presence of a truly unique hangar, while at other times the base acquired a hangar not only to accommodate a new aircraft but also to test as a prototype structure. The weights and balances test hangar, Building 1830, was another major hangar built on the Edwards flightline during the middle 1950s (Plate 35). The hangar featured a 360-foot arch, the longest such arch west of the Mississippi at the time of its construction. Building 1830 was 400 feet long, with 55-foot tall sliding doors. More importantly, the overall dimensions accommodated a clear opening of 300 feet wide by 50 feet tall. Again, the hangar could handle the B-36 or other very large future aircraft. The hangar's purpose was to support static tests on experimental aircraft, power plants, components, and related equipment for ARDC, including weights and balance testing. Engineers designed the weighing equipment into the hangar floor, while the structure was further engineered for wind loads and earthquake seismic forces.[77] The original floor scales were mechanical, capable of measurements up to 300,000 pounds and providing information on an aircraft's gross weight, centers of gravity, and fuel loadings. Weight distribution in an aircraft affects aerodynamic stability. Shifts due to fuel, cargo, and weapons require measurement and adjustment to recalibrate the modified aircraft. In 1969, AFSC added a set of electronic scales in the hangar. These scales were also capable of weights up to 300,000 pounds. The Air Force configured this equipment for the landing gear of the C-5A.[78] The C-5 was an extremely large cargo aircraft that underwent prototype testing at Edwards. The plane also supported testing of a prototype C-5 hangar at the installation (see below).

Planning for a weights and balances hangar dated to 1950, with construction at Edwards during 1956. The responsible architectural-engineering firm modeled Building 1830 directly on the 300-foot span, steel-arch hangars built at Idlewild Airport in New York, with acknowledgement in *Engineering News-Record*. The Idlewild hangars of 1949 were internationally known. The group of three steel-arch hangars were the work of engineer Anton Tedesko of the Chicago firm Roberts & Schaefer. Tedesko, an Austrian immigrant engineer trained in Germany, had arrived in the United States in the early 1930s to introduce Z-D thin-shell concrete construction on behalf of Dykerhoff & Widman. Their long- and short-barrel thin-shell reinforced concrete arch aircraft hangars were among the more exceptional engineering feats of World War II. Both the Navy and Army Air Forces commissioned

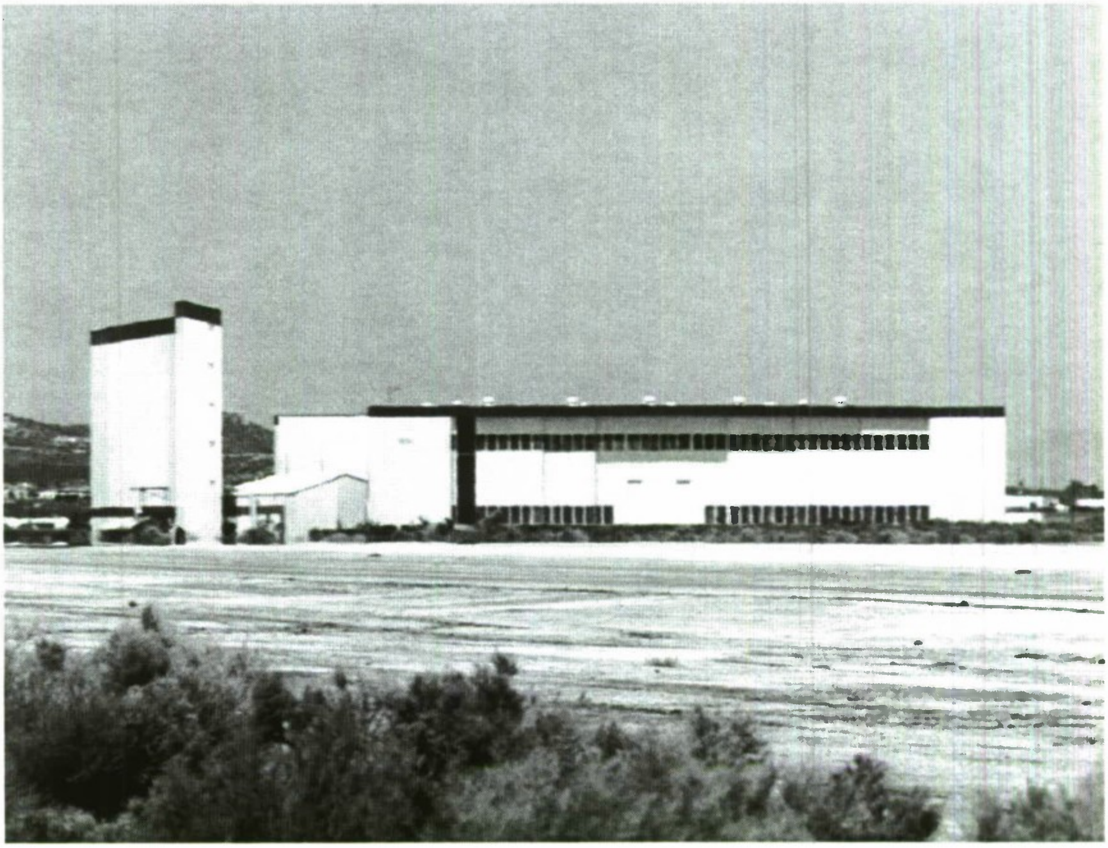

Plate 34: Kuljian Corporation. Basic Double-Cantilever Hangar (Building 1414), Edwards Air Force Base, 1955-1956. C-17 Parachute Tower on the left. View of April 1992. Courtesy of the History Office, Edwards Air Force Base.

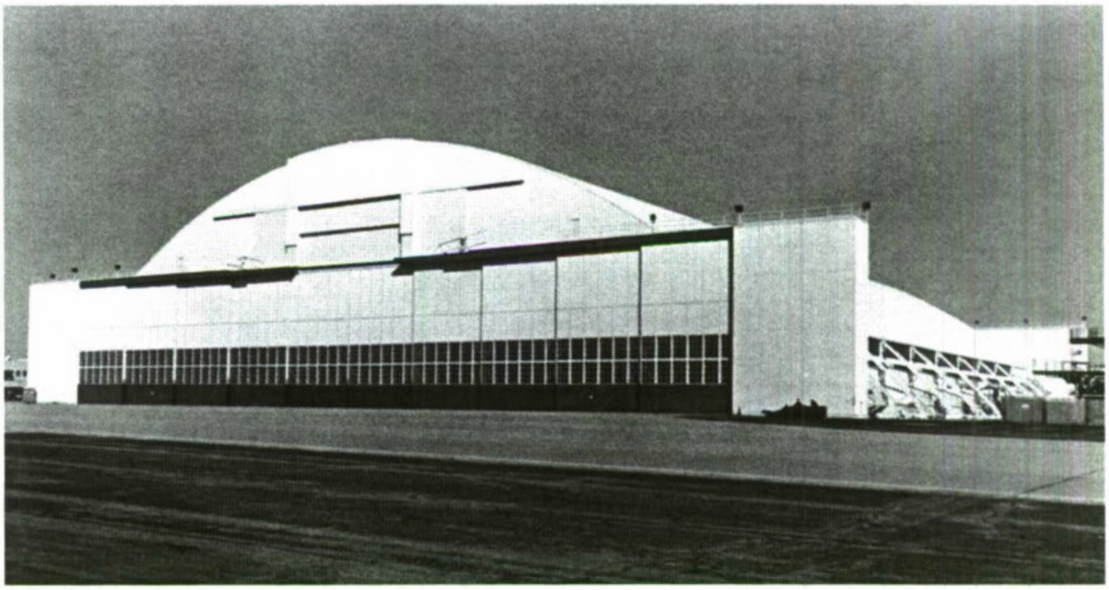

Plate 35: Anton Tedesko (attributed), with adaptation through Van Dyke & Barnes. Weights and Balances Hangar (Building 1830), Edwards Air Force Base, 1956. Photograph of April 2000. Installation Photographer, Edwards Air Force Base.

Tedesko's work, with a number of significant hangars erected at Wright Field in Dayton. Tedesko went on to design the 1947 thin-shell B-36 hangar for SAC and a major thin-shell warehouse for Air Materiel Command in 1957—with notable other accomplishments for the Air Force and Navy, as well as for civilian clients. Between 1955 and the early 1970s, Tedesko also served officially as an engineering advisor to the Air Force (see Volume I, Part II).[79] In discussing Building 1830, *Engineering News-Record* noted that Van Dyke & Barnes, the cited architectural-engineering firm, "reviewed several alternate designs for the Edwards hangar." The Los Angeles firm considered five variant designs: two triple-hinged, trussed steel-arch systems on 20- and 40-foot centers; two triple-hinged, plate-girder arch systems; and, a thin-shell, ribbed concrete arch system on 30-foot centers.[80] Tedesko had designed hangars in each of these specific systems, and his known work is strongly tied to specific thin-shell, ribbed concrete arch hangars of the period. Van Dyke & Barnes very likely had a set of standardized Tedesko drawings that had been executed for the Air Force and channeled through the Army Corps of Engineers. Of some additional note, Van Dyke & Barnes are also credited with the double-cantilever hangar at Edwards, a verifiable design of Kuljian Corporation and not of Van Dyke & Barnes.

Hangars suitable to support experimental flight testing of the future were a vital component of Edward's new infrastructure during the 1950s, including structures built to house contractors. Hangars accommodating very large aircraft were initially few, and in later years came to be represented through prefabricated open shelters. Hangars for fighter aircraft were more numerous on the flightline. These were initially drawn from standardized Air Force infrastructure developed for commands other than ARDC. As of mid-1953, 18 aircraft contractors worked in facilities at the Air Force Flight Test Center with 1,309 contractor personnel on base. North American Aviation was among the largest contractors at the installation, with 250 technicians. The firm primarily used facilities at North Base. North American Aviation's primary industrial plant abutted Los Angeles International Airport, adjacent to what would become the operating location of the AFBMD (later, Los Angeles Air Force Base). During 1953, North American Aviation tested the F-100 prototype and components of the F-86D, F-86F and F-86H. Northrop maintained 188 personnel on base. This company tested different versions of the F-89. Douglas worked on the Navy's D-558I, an aircraft that NASA would take over, and one of the X-series research planes, the X-3.[81] Hangars for contractors at the main base were under construction during the middle 1950s. Hangars No. 1, 2, and 3 are today's Buildings 1820 (No. 1 and 2) (Plate 36) and 1810 (No. 3). Each of these structures likely derives from a readiness / maintenance hangar originally designed for ADC to support its fighter-interceptor squadrons at bases across the country. Kuljian Corporation handled the design for this third-generation standardized structure, with drawings dating to 1955. The Air Force assigned Hangars No. 1 and 2 to Douglas, and No. 3 to Convair.[82] Initially, the Flight Test Center planned the hangars for Republic, Convair, and Douglas, with each of the hangars having an identical footprint and orientation.[83]

The Air Force also used other approaches to achieve its needed hangar infrastructure for the Flight Test Center. In 1957-1958, ARDC did not rely on standardized Air Force structures for Flight Test Hangars No. 1, 2, 3 and 4 (Buildings 1864, 1870, 1874, and 1881). Designed and engineered by Ralph M. Parsons Company of Los Angeles, the group of four identical hangars were contractor facilities from conception. General Electric handled the construction contract, not the Air Force or Army Corps of Engineers, and hired Parsons to execute the commission[84] (Plate 37). At the outset of the 1950s, Aerojet had also commissioned Ralph M. Parsons to design and engineer the test stand complex for Leuhman Ridge (see above). Both General Electric and Aerojet were prime contractors for test programs at Edwards, with the likelihood that General Electric turned to Parsons for its buildings due to that firm's preexisting similar role for Aerojet on the base. General Electric tested and maintained engines in Building 1864, later sharing the hangar with Northrop. North American Aviation was the early tenant for Building 1870. The firm first used the hangar for the X-15 program.

Plate 36: Kuljian Corporation. Douglas Hangars No. 1 and.2 (Building 1820), Edwards Air Force Base, 1955-1956. Photograph of April 2000. Installation Photographer, Edwards Air Force Base.

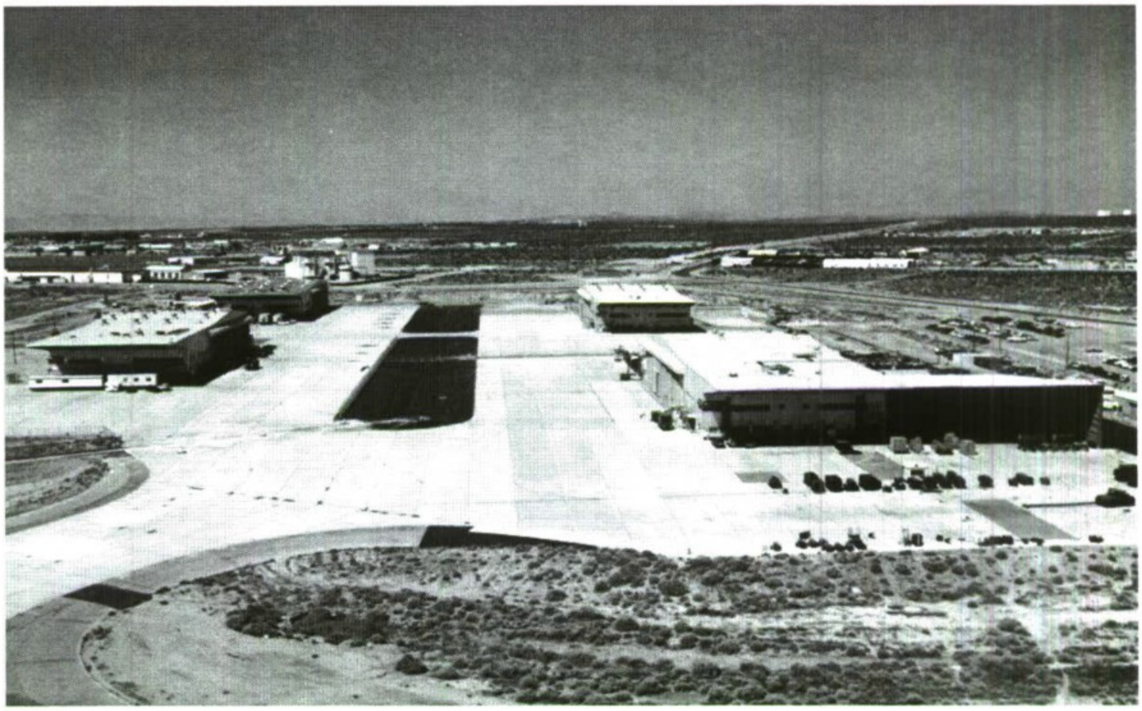

Plate 37: Ralph M. Parsons. Flight Test Hangars No. 1, 2, 3, and 4 (Buildings 1864, 1870, 1874, and 1881), Edwards Air Force Base, 1957-1958. View of June 1996. Courtesy of the History Office, Edwards Air Force Base.

Several contractors used Building 1874 throughout the Cold War, including Ling-Temco Vought, Inc., for maintenance of their A-7D, and later McDonnell-Douglas for two decades of work on the F-15. McDonnell-Douglas also dominated activities in Building 1881.

One additional example of infrastructure's importance to experimental flight testing was the hangar for the C-5. A very large cargo aircraft manufactured by Lockheed at Air Force Plant 6 in Marietta, Georgia, the C-5 required not only its own hangar, but also pavement testing. During the first half of 1966, the Directorate of Civil Engineering at Headquarters Air Force noted that a "new test hangar for the C-5A cargo transport aircraft is currently under design for Edwards AFB. A two-story shop and engineering building will be included in the project." In this instance, as in others of very high importance to the Air Force, the Directorate of Civil Engineering managed the hiring of an architectural-engineering firm to design a facility to meet pressing new needs. The contracted firm was typically of national standing, and usually based in the East or upper Midwest. For the prototype C-5 hangar to be erected at Edwards, the architect presented an initial design in mid-July 1966 before the Los Angeles District, Army Corps of Engineers. This situation suggests that the hired firm may have been planned to be regional (from Southern California), rather than national (from the established architectural centers in the East and upper Midwest) from the start. Aerojet Engineering signed off on the drawings for the hangar, which additionally suggests that Ralph M. Parsons is the "hidden" architectural-engineering firm for the contract. Decisions for the C-5 hangar by Headquarters Air Force also reflected the major role of AFBMD in not just contracting for missiles design and engineering, but also in managing the design process for missiles test stands and support buildings.[85] The Edwards C-5 hangar was to "serve as a basis of design for similar hangars at operating bases."[86] Military Airlift Command was the ultimate user for the C-5. By late 1967, AFSC, the Corps, and Military Airlift Command concluded that not only was a new hangar needed, but also pavement tests on existing airfields to determine dynamic loading challenges posed by the aircraft.[87] Construction on the C-5 hangar at Edwards, Building 1623, was underway after contract award in June 1967 (Plate 38). By early 1968, the Air Force awarded contracts for follow-on C-5 hangars for the Military Airlift Command installations of Charleston and Travis Air Force Bases in South Carolina and California, respectively. These hangars were identical to that at Edwards.[88] AFSC acquired responsibility for the C-5 pavement testing, and assigned the project to the Air Force Weapons Laboratory at Kirtland Air Force Base in New Mexico. The command ran at least one of the pavement tests at Altus Air Force Base in Oklahoma.[89]

The dimensions of the C-5, like those of the B-36 before it, triggered the need for its hangar.[90] The C-5 is nearly 248 feet long, with a wingspan of 222.75 feet and a tail height of just over 65 feet. The aircraft can weigh up to 840,000 pounds loaded, with a maximum load of 291,000 pounds. The C-5 requires a takeoff runway of 12,200 feet when fully loaded. Before the C-5 hangar, the Kuljian double-cantilever hangar had represented the Air Force "large-aircraft hangar" problem set (for the B-36). Engineers designed the double-cantilever hangar for an aircraft length of 162 feet, wingspan of 236 feet, and tail height of 49 feet. The XC-99, the experimental cargo version of the B-36 was longer still, at 182 feet, and had a tail height of 57.75 feet. The Air Force commissioned only a single XC-99 and assigned the aircraft to Kelly Air Force Base in San Antonio for operational testing (see Volume II, Chapter 7). The double-cantilever hangar of 1951 was sufficiently larger than the B-36 and XC-99 to allow personnel to do maintenance tasks inside the hangar. Tower shops in the hangar also served as support framework for the cantilever system. While the XC-99 of the early 1950s led directly to development of the C-5, the Lockheed cargo aircraft was too tall for the double-cantilever hangar (with its 65-foot tail and the hangar's 60-foot doors), and was nearly as long as the hangar was deep (248 feet to a standard depth of 250 feet). Thus, a new hangar for the C-5 was prototypical. The C-5 hangar focused on achieving a much greater length (304 feet) and a slightly taller door. The problem did not necessitate unusual cantilevering, or expansibility, but did mandate an entirely new hangar. As was true for the double-cantilever hangar before it, that for the C-5 functioned for later

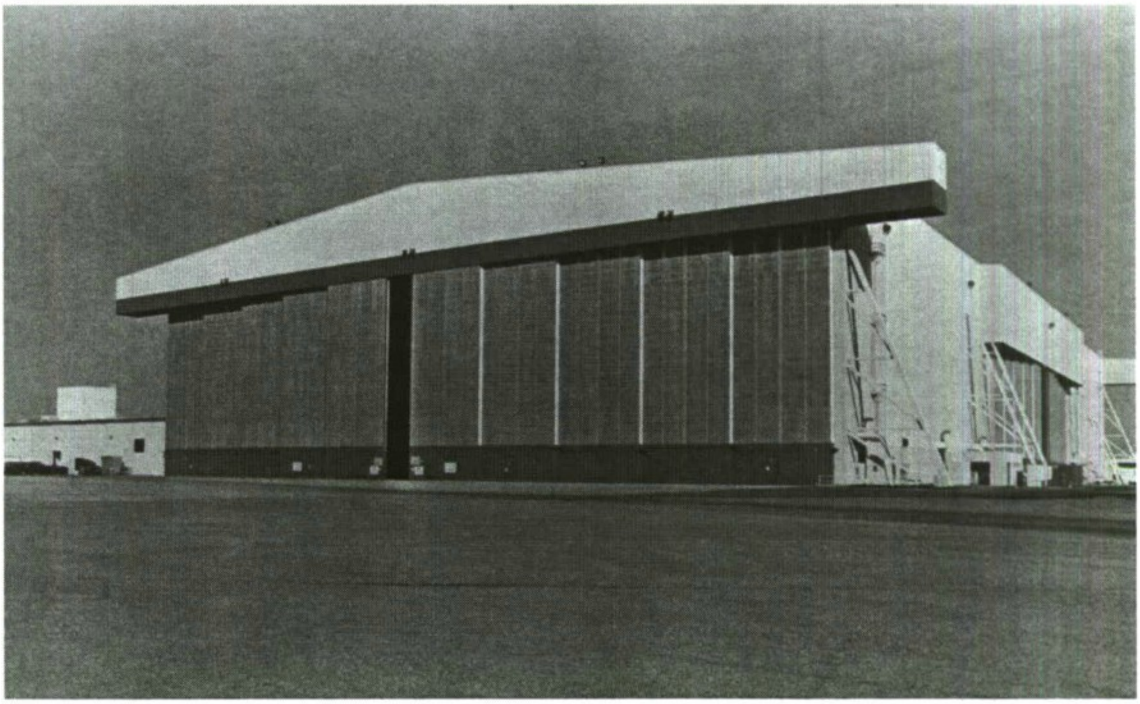

Plate 38: Ralph M. Parsons (attributed) and Aerojet. C-5 Hangar (Building 1623), Edwards Air Force Base, 1967. Photograph of April 2000. Installation Photographer, Edwards Air Force Base.

aircraft at Edwards—first for testing of the B-1 bomber over a two-decade period and, after the Cold War's end, for the C-17 cargo aircraft.

During the 1950s the Air Force Flight Test Center tested experimental and prototype aircraft including the F-100 fighter series; the X supersonic research series; the C-130, C-133, the C-140 transport aircraft; and, adaptations of the B-52 and the RB (reconnaissance bomber) -66. The Flight Test Center simultaneously expanded its static test stand facilities and added a test track on Hurricane Mesa in Utah. NACA (and as of 1958 its follow-on agency NASA) concentrated on the X-series high-speed aircraft of sweptwing, semi-tailless, delta-wing, variable-sweep, and thin-wing aerodynamic vehicles, with some launched from B-29s and B-52s. Engineers incorporated achievements and data gained from the X-series into developmental aircraft, particularly the F-100 fighter series, the U-2, and the SR-71. NASA's role at Edwards grew dramatically after the late 1950s, with a separate area established for the agency (see Volume 1, Part IV). NASA maintained its own static rocket engine test stands at Edwards in distinct areas on base. On Leuhman Ridge, NASA rocket engine testing furthered research toward the agency's satellite and spacecraft launch vehicles. NASA sponsored satellite propulsion tests at Test Area 1-14 on the ridge, with considerable experimentation with Atlas ICBM and Thor intermediate range ballistic missile (IRBM) launch vehicles. Area 1-21, built for Bomarc testing, accommodated data gathering on the X-15 engine.[91] In 1958, the Air Force Flight Test Center also acquired management of a 12,000-foot test track on Hurricane Mesa in Utah. Built in 1955 and operated by the Coleman Engineering Company of Torrance, California (at first called the Coleman Track), the Hurricane Mesa track sits at the edge of a 1,500-foot precipice above the Virgin River west of Zion National Park (Plate 39). The Wright Air Development Center at Wright-Patterson initially managed the test track to simulate a supersonic flight environment to test ejection seats and other test equipment. The track included a 2,800-foot water break for deceleration. The Wright Air Development Center allowed for a future extension of

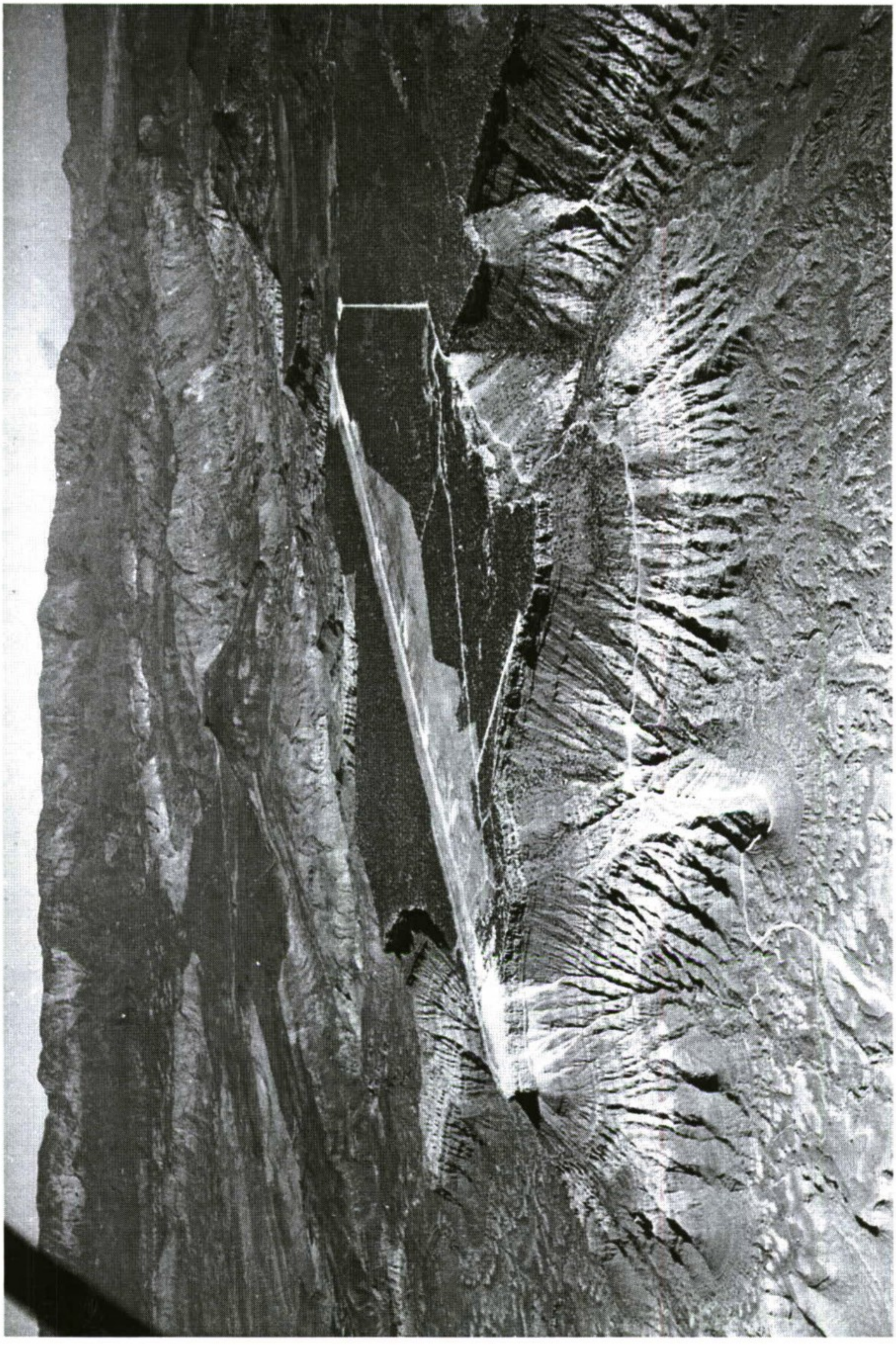

Plate 39: Coleman Engineering. Supersonic Military Air Research Track (SMART), Hurricane Mesa, Utah, ca.1955-1958. In Coleman Engineering, *The Fact Book of Project SMART*, ca. 1958. Courtesy of the History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.

the track to 17,000 feet, including a modification of the water break to 5,000 feet. As designed, the official Air Force name for the track was the Supersonic Military Air Research Track (SMART). Test personnel used the facility for high-speed captive tests and free-flight tests, the latter including free fall of test objects over the cliff. With acquisition by the Air Force Flight Test Center, the track became known as the Hurricane Supersonic Research Center. The Air Force Flight Test Center used the facility for air-to-air missile tests. Edwards personnel also evaluated the track as a free-flight launcher for large-stage missiles and space vehicles. First Air Force Flight Test Center experiments on Hurricane Mesa in 1958 focused on the escape capsule for the X-15, as well as on the testing of high-speed parachutes, with parachute performance limits pushed to Mach 1.5.[92]

The X-15 studies led toward spaceflight, both in achieved altitude and speed. The X-15, a rocket-powered, manned vehicle, was the first hypersonic aircraft (able to break Mach 5, or about a mile a second). North American Aviation's X-15 arrived at Edwards for testing in autumn 1958, with the program fully underway in early 1961.[93] In October 1967, the X-15 set a speed record of Mach 6.7. (The fastest air-breathing aircraft is the SR-71, capable of flying at just above Mach 3, or 2,100 miles per hour.) The X-15 engine test complex, sited east of the 1800-series contractor hangars on the main base flightline, included two static test stands (for engines only and for the complete X-15 vehicle), a concrete blockhouse, underground observation pits, associated shops, and water supply structures. The complex was under construction between 1958 and 1960 (Plate 40).[94] As of mid-1959, ARDC proposed a 15,500-foot runway for "Project X" on the opposite shore of Rogers Dry Lake southeast

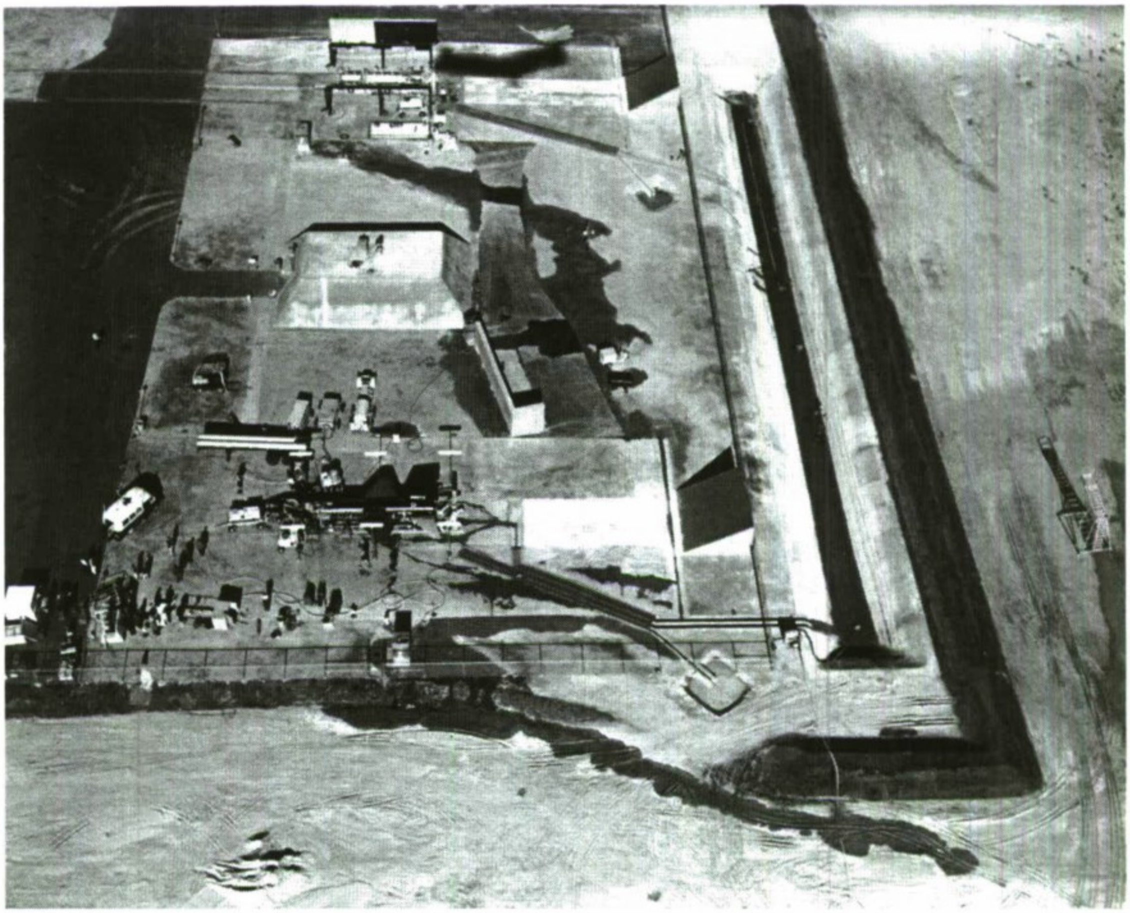

Plate 40: X-15 Test Complex, Air Force Flight Test Center, Edwards Air Force Base, 10 March 1959. Courtesy of the History Office, Edwards Air Force Base.

of South Base (Plate 41). (The runway would have been comparable to the existing 15,000-foot facility at the main base, but it remained unbuilt.) All tests of the X-15 occurred at Edwards, through the last test flight in November 1968. Test personnel dropped the X-15 from a B-52 mothership at an altitude of 45,000 feet and a speed of 500 miles per hour. The X-15 then flew on a predetermined path and landed on the Rogers Dry Lake. North American Aviation built three X-15s for the 199 missions conducted at the Air Force Flight Test Center. The X-15 program also included a mockup for an attached scramjet (<u>s</u>upersonic <u>c</u>ombustion <u>ram</u> jet) engine planned to give the aircraft more altitude and speed.[95] As the decade of the 1960s opened, the X-15 was a very high-profile aircraft project. In late 1961, the American government sought to showcase the achievement of the hypersonic aircraft in a movie released for public distribution entitled *X-15*. United Artists produced the film in cooperation with NASA, the Department of Defense, the Air Force, the Navy, and North American Aviation. *X-15*'s star was Mary Tyler Moore of the *Dick Van Dyke Show*, in her debut movie role.[96] (A film of 1954, *Strategic Air Command* starring James Stewart and June Allison, had similarly glorified the B-36 and the B-47.) Although the X-15 program was cancelled before the deployment of a working model, research achievements associated with the X-15 helped lead to today's scramjet-powered X vehicle, the X-43A. The X-43A, an air-breathing and unmanned test vehicle, is launched from a modified B-52 in a manner paralleling launch for the X-15. NASA engineered the X-43 to break Mach 7, but the first flight tests at Edwards in early June 2001 failed. A year later, on 30 July 2002, an Australian research team successfully launched a rocket with an attached hypersonic HyShot engine at the British Woomera Proving Ground and reached Mach 7.6. The HyShot team, like that of NASA, had suffered a previous failed test. Until the HyShot test at Woomera, the X-15 record of 6.7 had remained unbroken for nearly 35 years.[97]

During 1957-1958, the Air Force augmented its static test stands on and near Leuhman Ridge, with stands 1-1, 1-2, 1-A, and 1-95 activated for ICBM and IRBM testing[98] (Plate 42). To the immediate east and southeast of the ridge, the Air Force developed discontiguous clusters of laboratory and test sites. Test Area 1-30 for example, built in 1957, featured facilities for nose cone tests and propellant evaluation. The Air Force Flight Test Center used Test Area 1-46 (begun in 1956) for propellant studies, and Test Area 1-60 (initiated in 1957) for aerospace chemical laboratory experiments.[99] At this same time, the JPL added static rocket motor test stands at its facilities near North Base. As of 1957, the JPL began construction for Test Stand C. In 1958, NASA acquired the JPL and initiated construction for Test Stand D. Ancillary structures accompanied both new test stands for the JPL area.[100] In yet another development, at an isolated Air Force site to the northeast of Leuhman Ridge, a tethered-silo complex for Minuteman I ushered in both new testing techniques and future launch complex configurations. Test Area 1-100 was operational by September 1959. The complex featured two identical test silos 26 feet in diameter and 144 feet deep, blockhouse (with both above- and belowground firing control rooms), shop, and missile assembly building. Earlier in the year, AFSC and Boeing had initiated experiments to demonstrate the feasibility of launching ICBMs from underground silos.[101] *Aviation Week* published a photograph of Test Area 1-100 in June 1960 that showed the silo complex with a horizontal retractable Thor launch shelter sheathing the test missile.

While the Air Force had schematically planned for ICBMs to be stored vertically in a launch position in hardened underground silos from as early as December 1955, the technology required to achieve the feat was not immediate. As of May 1958, the AFBMD revised its ICBM development plan for operational Atlas sites. The first four squadrons were to be "soft," fully aboveground configurations using steel gantry towers and horizontal reinforced concrete storage structures known as "coffins." The final five squadrons would be "semi-hardened," stored horizontally below ground in a protected configuration that was improved over earlier launchers but that was not truly hardened. The goal remained deep vertical underground storage and, as of 1958, launch from within a silo (for Titan II) with minimal exposure time. In July 1958, the Air Force Ballistic Missiles Committee also approved the Minuteman. The Air Force planned to use a transitional launch mode for its first underground

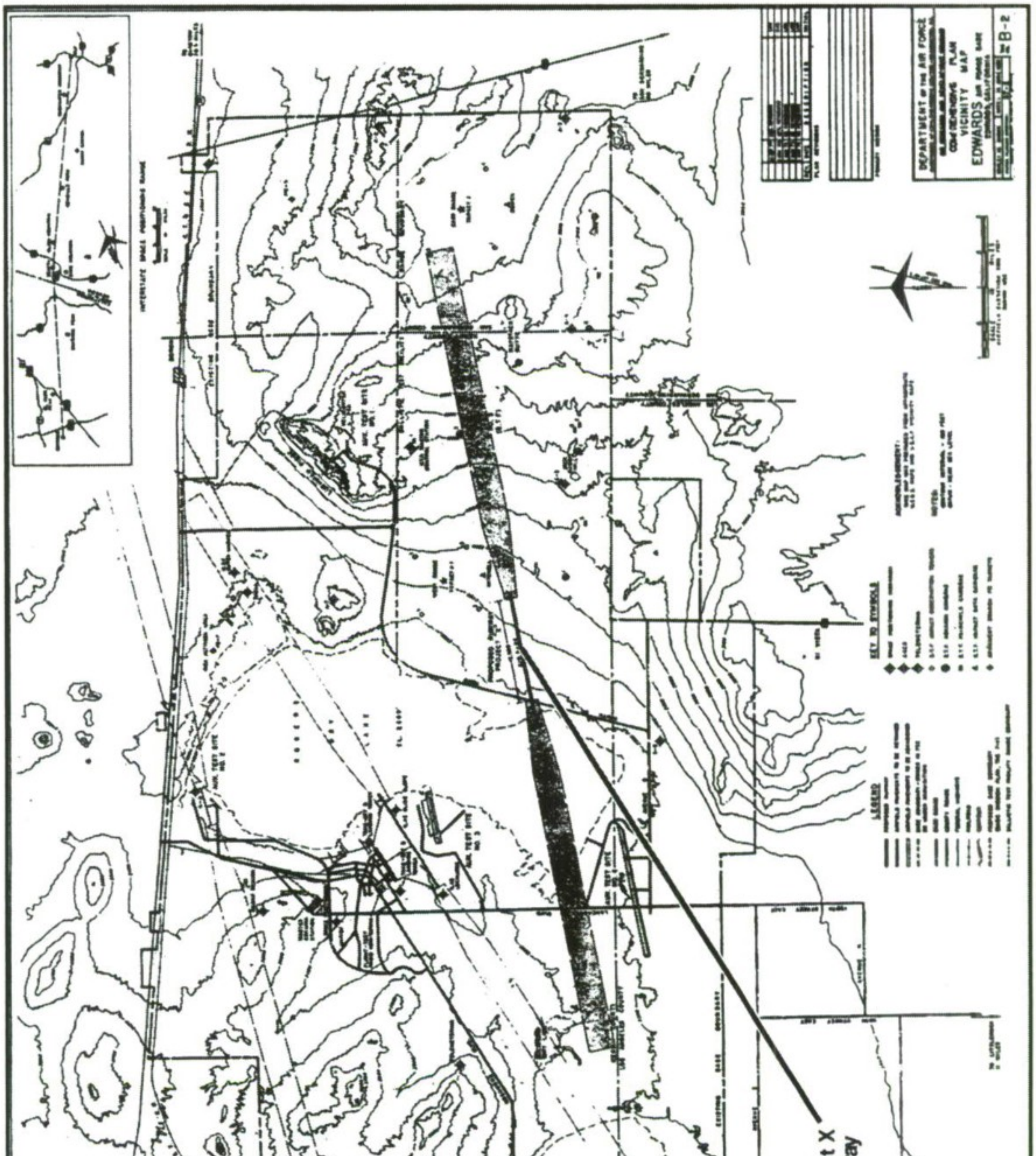

Plate 41: Directorate of Civil Engineering, Headquarters United States Air Force. Comprehensive Plan for Edwards Air Force Base, 19 June 1959. Annotation added. Courtesy of Civil Engineering, Edwards Air Force Base.

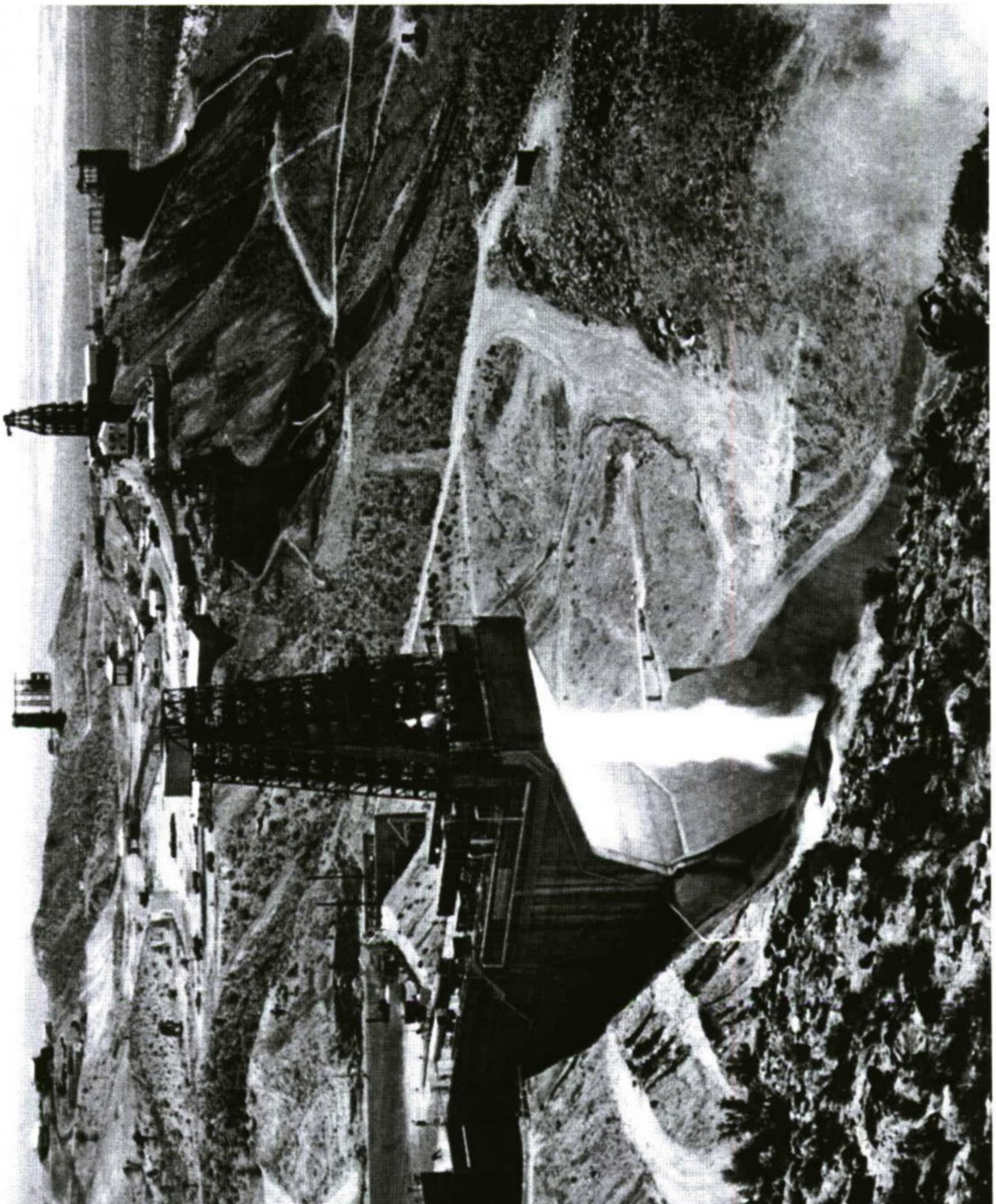

Plate 42: Atlas ICBM Hot Firing in Test Stand 1-A, Leuhman Ridge, Edwards Air Force Base, 1 August 1957. Courtesy of the History Office, Edwards Air Force Base.

silos. For these launchers, engineers raised the ICBMs (Atlas F and Titan I) to the surface via elevators for firing.[102] As of March 1959, personnel launched scaled-down test rockets 2.75 inches thick from underground.[103] While these tests went forward, launch complexes for the Atlas, Titan, and Minuteman ICBMs continued to be of overlapping and variant types: soft aboveground (gantry and coffin); horizontal, semi-hardened belowground; elevator-silo launch; and, in-silo. In April, the AFBMD and the ICBM Scientific Advisory Committee revised projected operational dates for launch of the Atlas D from aboveground complexes, due to flight testing problems at ARDC's Missile Test Center at Patrick Air Force Base in Florida (with test stands located 20 miles north at Cape Canaveral Air Force Station). Not until July 1959 did the Air Force Ballistic Missiles Committee approve the technique of launching ICBMs from a vertical position within an underground silo.

By mid-1959, plans for the smaller, solid-propellant Minuteman included launch from within an underground silo as well as a rail-mobile launch[104] (the latter tested at Hill Air Force Base in Utah) (see Volume II, Chapter 6). Air Force personnel continued conceptual testing for launch from an underground silo, using one-third scale and full-scale Minuteman missiles. For the full-scale Minuteman I, silo launches at Edwards were "tethered." Engineers attached a 2,000-foot nylon cable to the missiles for the tests. The first of these tethered Minuteman launches occurred at Edwards in mid-September 1959, with seven more launches following (Plate 43). Personnel launched a Minuteman first-stage motor from one of the Area 1-100 silos. The experiment proved the concept of launching from within a silo, rather than raising the ICBM to ground level (as in Atlas and Titan I silo

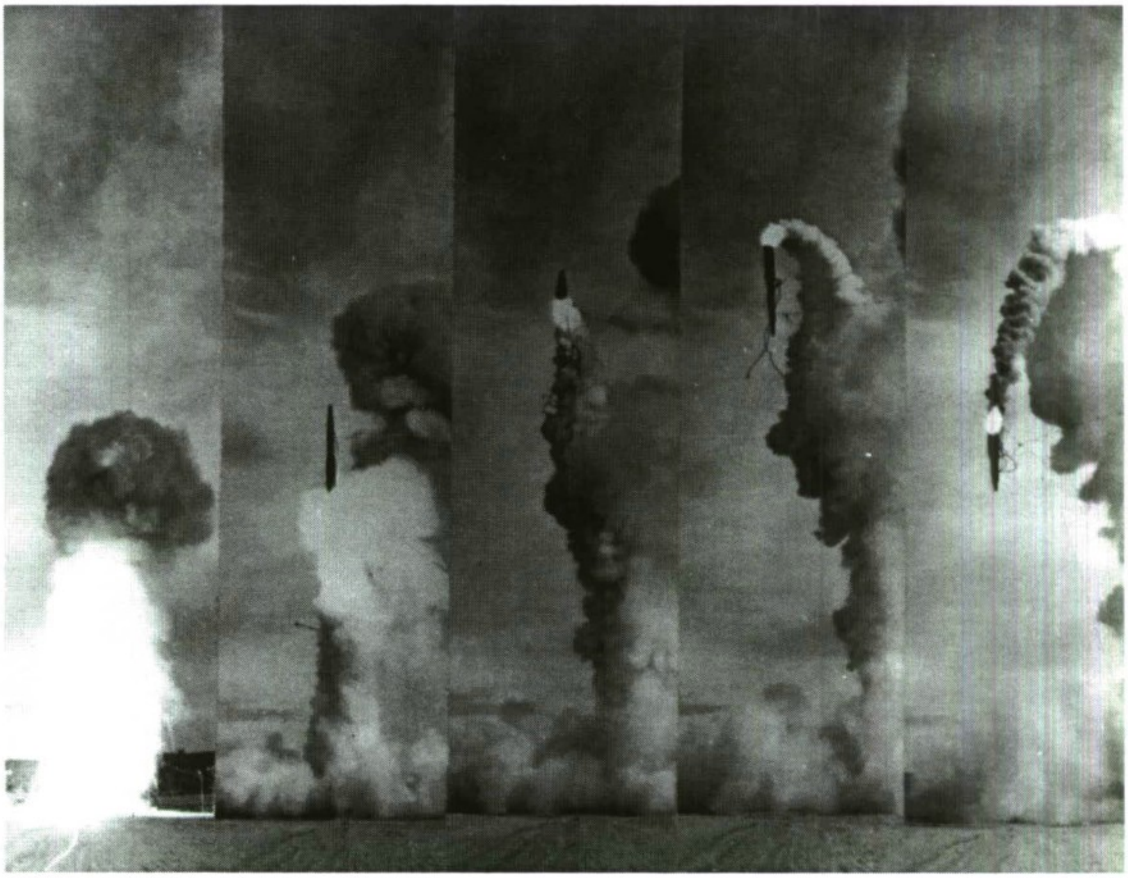

Plate 43: Tethered Minuteman I, Area 1-100, Vicinity of Leuhman Ridge, Edwards Air Force Base, 1960. Minuteman I test with three full stages. Courtesy of the History Office, Hill Air Force Base.

launches).[105] The AFBMD had originally planned for 18 tethered Minuteman I tests at Edwards, but the division was able to accelerate its evaluations and required only eight test launches at Area 1-100. The final Minuteman I test launch at Edwards occurred on 6 May 1960, moving the program up by six months.[106] The AFBMD's first "all up" test was successful at the Air Force Missile Test Center at Patrick on 1 February 1961 from an aboveground gantry. The free-flight test at Patrick impacted at sea on the Atlantic Missile Test Range 4,600 miles from its launch site.[107] On 3 May 1961, the Air Force successfully launched its first ICBM from within an underground silo, a Titan II, at Vandenberg Air Force Base in Southern California.[108] In November 1961, the AFBMD next launched a complete three-stage Minuteman I from a silo at Vandenberg, with the missile flying 3,000 miles across the Pacific Missile Test Range.[109] On 1 March 1965, SAC launched the first Minuteman I from an operational base. The launch from a Minuteman I silo near Ellsworth Air Force Base in South Dakota was a final test and used a short-range, unarmed Minuteman I in a tethered configuration.[110] During the 1970s, AFSC personnel launched the first tethered Peacekeeper ICBM using the Minuteman silos in Edwards' Test Area 1-100.[111] Ralph M. Parsons designed the operational silo for the Minuteman I, and was also responsible for the improved Minuteman II silo (see Volume II, Chapter 6). Of note, Anton Tedesko was involved in the design and engineering of the ground support equipment for the Minuteman through the AFBMD, including the underground control centers for the silos and the training facilities built at Chanute Air Force Base in Illinois and Vandenberg in California (see Volume I, Part II).

ARDC and AFSC completed the major infrastructure for the Air Force Flight Test Center during the 1960s, adding static test stands on Leuhman Ridge and at NASA's JPL area, as well as discontiguous test complexes and support facilities. The Air Force augmented the ridge with eight test stands in Test Areas 1-36, 1-56, 1-120, and 1-125. Projects included continued testing for Atlas, Saturn V booster, the F-1 engine (for the Saturn V), and Titan III and IV motors, among others. The Flight Test Center also added more test cells and individual test pads. (Parsons-Aerojet is the likely engineering firm responsible for some—or all—of these facilities. By 1962, Aerojet was designing a Saturn V static test stand and an F-1 engine test stand at NASA's Marshall Space Flight Center in Alabama.[112]) For the Minuteman, the Flight Test Center augmented its facilities near Leuhman Ridge with more test support (Test Area 1-32); a static test area for large solid propellant motors (Test Area 1-36); a simulated space environment test complex for testing ballistic missiles, launch vehicles, and satellites (Test Area 1-42); a large motors operations area for rocket combustion research with vertical and horizontal firing pads (Test Area 1-52); and, a high-thrust rocket research facility (Test Area 1-56). As of mid-decade, AFSC added Air Force Plant 72 on the southern side of Leuhman Ridge for the on-site production of LOX and the vaporization of liquid nitrogen.[113] NASA also expanded its operations at the JPL test station. JPL moved its solid-propellant manufacturing and testing facilities from Pasadena to Edwards during the early 1960s. The new complex in the JPL area on base, including Test Stand E, gave NASA in-house capabilities to process and test solid propellants. Test Stand E initially supported NASA's commercial satellite and spaceflight programs.[114]

Flight testing and large rocket motor data gathering continued throughout the 1960s until the end of the Cold War, and is still active today. AFSC personnel tested the Lockheed U-2, C-5, and F-22, the Ling-Temco Vought A-7, the McDonnell Douglas F-15 and C-17, General Dynamics F-16, the Rockwell B-1, the Fairchild A-10, and the Northrop F-5, F-17, F-20, F-23, and B2, in prototype and production versions.[115] A separate B-2 flight test area went in place at Edwards during 1985-1988. The B-2 compound included a large maintenance hangar, 574 feet wide by 304 feet deep; a jet engine maintenance shop; several structures in the weapons storage area; an integrated maintenance facility; and, multiple research engineering support buildings. Associated with the B-2 (and also with the B-52) was a new weapons system, the Short-Range Attack Missile (SRAM). The SRAM is a nuclear cruise missile that upgraded SAC B-52 alert wings at selected bases in the United States after 1985.[116]

Other test programs of the Air Force and NASA (see Volume I, Part IV) at Edwards during the later Cold War featured research toward the Dyna-Soar (X-20) and the Space Shuttle; Rogallo wing reentry studies; maintenance and flight of the airborne Argus testbed; lunar landing research and test; kinetic energy weapons research toward the SDI program; solar energy and electric propulsion studies; and, Space Shuttle responsibilities for landing on Rogers Dry Lake as well as responsibilities for maintenance, refitting, and mating for transport back to the Kennedy Space Center.

Key Associated Architects and Engineers

Major architectural and engineering firms responsible for buildings and structures at Edwards Air Force Base are somewhat difficult to determine. Selected buildings illustrate a practice of substituting the names of local firms in the title blocks of drawings—thereby obscuring the names of the firms that the Air Force hired to handle a national-level building program (for example, the double-cantilever hangar). In other instances, test infrastructure carries the names of California aircraft and civil engineering firms. In these cases, the firms would have subcontracted building projects to an architectural-engineering firm, rather than carry out the work in-house. Known firms of note at Edwards included:

- Kuljian Corporation, of Philadelphia;
- L.G. LeTourneau, of Longview, Texas;
- Ralph M. Parsons, of Los Angeles; and,
- Pereira & Luckman, of Los Angeles.

The behind-the-scenes presence of Anton Tedesko for the design of the weights and balances hangar (Building 1830) is also highly likely. Tedesko's work for thin-shell, reinforced concrete hangars and warehouses, as well as for long-span, hinged steel-arch hangars (as for Building 1830) is of international significance for the 1939-1950 period (see Volume I, Parts II and III, and Volume II, Chapter 14).

Kuljian Corporation

For Kuljian Corporation, the firm's Air Force prominence began with the nationwide commission for the double-cantilever hangar in 1951 (at Edwards, Building 1414). Dr. Harry A. Kuljian founded the Kuljian Corporation in 1930. Dr. Kuljian, who was Armenian, immigrated to the United States from Turkey just before World War I. He graduated from the Massachusetts Institute of Technology, and subsequently worked for two power companies and American Viscose (a company that manufactured rayon). When Dr. Kuljian went into business for himself, he leveraged his expertise in power plant and textile industry engineering to design captive power generation for eight rayon production sites in the United States and Canada. During World War II, the Navy hired Kuljian to design power plants at multiple Naval yards on the East Coast and at Subic Bay in the Philippines. The firm also undertook some work in regional transportation engineering. In 1949-1950, Kuljian handled the engineering for the expansion of the Philadelphia airport. Kuljian Corporation's chief engineer-architect, Walter Fasshauer, was the individual responsible for the SAC double-cantilever hangar of 1951. The double-cantilever hangar was the firm's first Air Force work. At the time Kuljian accepted the commission, at least one other firm had tried to design this hangar, with a complicated and as yet unresolved lineage of earlier efforts. Fasshauer, of German descent, had been with Kuljian since 1934.

After the success of the Kuljian double-cantilever hangar, the Air Force hired the firm to design the 1,104,000 square-foot B-52 maintenance and modification hangar at Kelly (originally also planned for Robins Air Force Base in Georgia); a readiness / maintenance hangar for fighter aircraft at

Edwards and multiple ADC installations; a weapons calibration shelter and armament / electronics shop for the F-101B at many ADC bases; a de-icing hangar at Loring Air Force Base in Maine; and, a modification and overhaul hangar at Olmsted Air Force Base in Pennsylvania (the former Middletown Air Materiel Area depot). Major projects for the Army included a chemical warfare plant at Rocky Mountain Arsenal, Colorado, and a decontamination test facility at the Edgewood Arsenal, Maryland.[117] Kuljian Corporation undertook a large amount of work in the Middle and Far East as of the middle 1950s. By 1958, fully 75 percent of the firm's work was overseas, with substantial foreign-government projects in India, Pakistan, Iran, Iraq, and Korea. Kuljian designed a 10,000-foot runway for the airport in Karachi, Pakistan, during 1958-1960.[118] Kuljian Corporation continues today, based in Philadelphia, and with a strong continued presence in the Middle East.

R.G. LeTourneau

Robert Gilmour LeTourneau (1888-1972) was an entrepreneur based first in central California. Born in New England, and arriving in California by way of Minnesota and Oregon, R.G. LeTourneau was largely self-taught—working as an iron molder early in his industrial career. As of 1920, R.G. LeTourneau began manufacturing a welded scraper in his plant in Stockton. LeTourneau's equipment featured pioneering self-loaders, scrapers, and self-spreading machines. LeTourneau incorporated as a California stock company in 1929, building a second plant to make heavy grading equipment. In 1935, the LeTourneau enterprise moved its headquarters to Peoria, Illinois, and erected a branch plant there. As of 1937, the company expanded to manufacture steel buildings. The structures were steel-panel in type, configured as products similar to those of the long-established Butler Manufacturing in Kansas City. (A number of such companies existed in the Midwest.) The LeTourneau buildings relied on modular construction. Each module functioned like a thermos bottle—an analogy LeTourneau used for marketing—"cool in the summer, warm in winter." LeTourneau built 30 steel-panel houses, LeTourneau Court, immediately adjacent to the company plant in Peoria. These first houses varied from 576 to about 857 square feet.[119] In 1939, LeTourneau, Inc., erected a third plant in Toccoa, Georgia, that featured an even larger group of all-steel buildings. The Toccoa airport included LeTourneau steel hangars. The Louise Farming Corporation, another LeTourneau enterprise, featured all-steel barns, as well as an all-steel hotel fanning out as one-story wings from a domed center section.[120] R.G. LeTourneau, Inc., continued to manufacture heavy grading equipment during the company's expansion into steel buildings, and during World War II LeTourneau earth-moving equipment was a mainstay for constructing military airfields and conducting compacting tests. LeTourneau manufactured more than 70 percent of such equipment for the armed services during the war.[121] As of early 1946, R.G. LeTourneau moved its headquarters from Peoria to Longview, Texas, where the company remains as a major enterprise today manufacturing heavy equipment and marine rigs. During 1951, R.G. LeTourneau sold most of his earth-moving equipment business to the Westinghouse Air Brake Company for $31,000,000. As a part of the deal with Westinghouse, LeTourneau agreed not to start another competitive company for five years. After 1958 however, R.G. LeTourneau rose again as a manufacturer of heavy equipment. This later work included producing missile transports for the Army and offshore marine rigs.[122]

Ralph M. Parsons

At least as of 1948, Ralph M. Parsons was handling architectural-engineering contracts for complex and unusual military R&D complexes. A major accomplishment of the firm in that year was the design of the technical facilities for the development of atomic weapons at Los Alamos, New Mexico. In 1952, Air Materiel Command hired Parsons to evaluate hot-agent test facilities for biological warfare munitions at Eglin Air Force Base in Florida (see Volume II, Chapter 4). Nearly simultaneously, the Air Force and Army hired the firm to design large missile facilities at Edwards (on Leuhman Ridge) and the Redstone Arsenal in Huntsville, Alabama. These two installations were

both major, and included test stands, blockhouses, control stations, instrumentation, handling equipment, propellant storage, and laboratories. By the middle 1950s, Ralph M. Parsons had assumed a leadership position within the architectural-engineering industry with regards to aviation and missiles structures, in particular. Parsons participated in the Air Force and Navy nuclear-powered aircraft program (see Volume II, Chapters 8 and 15); the IRBM program; high energy fuel development; and, nuclear reactor design. Examples of Ralph M. Parsons designs before 1957 included test facilities for nuclear engineering development at the National Reactor Test Station in Idaho; a nuclear reactor and engineering facilities at Wright-Patterson Air Force Base in Ohio (see Volume II, Chapter 14); and, underground bulk fuel storage facilities for SAC worldwide. At the close of the 1950s into the middle 1960s, Parsons designed launch silos for the Titan I and II, as well as for the Minuteman I and II. A later Cold War key test facility handled by the firm was the Missile X (MX / Peacekeeper) ICBM buried trench project on the Luke Bombing and Gunnery Range in Arizona of 1977-1978 (see Volume II, Chapter 9). By the later 1950s, Ralph M. Parsons sometimes worked in direct partnership with Aerojet Engineering as Parsons-Aerojet. Today, the firm is part of a very large Parsons engineering conglomerate and continues to execute substantial military contracts. A current project is evocative of Parsons' specialized expertise: a $10-million explosive test complex for the Department of Defense at Indian Head, Maryland.[123]

Pereira & Luckman

The Los Angeles firm of Pereira & Luckman (later, William L. Pereira & Associates and Charles Luckman & Associates) established itself as a prominent post-World War II architectural-engineering firm responsible not only for well-known commissions in California, but also for significant military contracting for installation master plans. Between 1950 and 1955, Pereira & Luckman handled the master plans of six Air Force bases and Air Force Plant 42 in the continental United States. The installations included three ARDC bases with missions tied to missiles testing: Edwards in California, Patrick (Air Force Missile Test Center) in Florida, and Holloman (Air Force Missile Development Center) in New Mexico. Pereira & Luckman's work for the Palmdale plant was as a subcontractor to Lockheed Aircraft Company, under an Air Materiel Command contract. For Air Force Plant 42, the firm had a separate contract approaching one million dollars. Pereira & Luckman prepared working drawings and specifications for the plant, and also supervised construction activities. The firm's master plans for installations under other commands included Nellis, Williams, and Luke Air Force Bases in Nevada and Arizona, all for Air Training Command. Pereira & Luckman was among the four architectural-engineering firms that undertook the master planning for SAC's bases in Spain during the middle 1950s. The joint venture included Pereira & Luckman; Shaw, Metz & Dolio; Metcalf & Eddy; and, Frederick R. Harris. The Navy's Bureau of Yards and Docks oversaw this very important project for the Air Force.[124]

In California, Pereira & Luckman (and its successor firms William L. Pereira & Associates and Charles Luckman & Associates) put together a prominent practice. The firm achieved both national and international standing in the architectural profession. Pereira & Luckman vacillated between a corporate International Style emphasizing an extremely reductive aesthetic and a whimsical post-Modern style of unusual geometrical shapes. Early commissions by Pereira & Luckman included the CBS (Columbia Broadcasting System) Television City office complex of 1952, a sleek rectangular structure featuring all-glass facades in Los Angeles; Marineland in Palos Verdes of 1954; the Signal Oil Company office tower in Los Angeles of 1958; and, the Southern California School of Theology in Claremont of 1960-1961. As William L. Pereira & Associates—the primary spinoff from the original firm—notable commissions included the master plan and terminals for the Los Angeles International Airport of 1959-1962 (a design that featured a dramatic central elevated restaurant shaped like a flying saucer); multiple buildings at the University of Southern California, Occidental College, University of California at Irvine, University of California at Santa Barbara, and University

of California at San Diego, during 1963-1973; the Los Angeles County Museum of Art of 1964; the Dickenson Art Center at the University of California at Los Angeles of 1965; Pepperdine University in Malibu of 1971-1973; the Great Western Savings Center in West Hollywood of 1972; the Transamerica Pyramid in San Francisco of 1972; and, the office tower for the Ralph M. Parsons Company in Pasadena in 1974. Charles Luckman & Associates' work included Federal and civic buildings, as well as office complexes.[125]

---

[1] Readers can clarify lineage issues for Edwards Air Force Base by referring to Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume I of *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). Information contained in the volume includes: source of the installation's name; current and past names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and a year-by-year indexing of units assigned to the base.

[2] David D. Earle, Kelly A. Lark, Cole J. Parker, Margaret R. Ronning, and Jackson Underwood, *Overview of Historic Cultural Resources*, volume 2 of *Cultural Resources Overview and Management Plan for Edwards AFB, California* (Edwards Flight Test Center: Computer Sciences Corporation, March 1998), 17-83.

[3] Cary D. Cotterman, Scott M. Hudlow, Linda Auten, Christopher O. Hurst, Dena S. Komporlides, and Susan L. Bupp, *Inventory and Evaluation of Selected Military Period Structures at South Base, Edwards Air Force Base, California*, volume 1 (San Bernardino, California: Tetra Tech, Inc., October 1997), 6-63; Karen J. Weitze and Lori Lilburn, field visit to the former George Air Force Base, April 2000.

[4] James O. Young, Raymond L. Puffer, and Frederick A. Johnson, "The Air Force Flight Test Center," typescript of a draft essay composed for the History Office at Headquarters United States Air Force, 30 January 1996, 1-2.

[5] *Ibid*, 2.

[6] Earle, Lark, Parker, Ronning, and Underwood, *Overview of Historic Cultural Resources*, 1998, 83.

[7] Karen J. Weitze, *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970*, Holloman Air Force Base Cultural Resources Publication No. 5 (El Paso: Geo-Marine, Inc., for Air Combat Command), November 1997, xx-xxiii ("Missiles Terminology, Prefixes, and Coding").

[8] Richard F. McMullen, Aerospace Defense Command History Office, *An Overview of Air Defense Command Weapons 1946-1972*, Air Defense Command Historical Study No. 39, 1973, 13.

[9] Joseph Trnka, Laura Taylor Lambros, and Norman Rajotte, *Historic Building Inventory and Evaluation of Air Force Plant 42, Palmdale, California* (Colton, California, and Golden, Colorado: Earth Tech, Inc., and Research Management Consultants, Inc., March 1997), 3-22 – 3-30.

[10] Young, Puffer, and Johnson, "The Air Force Flight Test Center," 1996, 3.

[11] George Cully, Air Force Research Laboratory, History Office, Wright-Patterson Air Force Base, "MX List," draft research, 21 November 2001.

[12] Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960* (Washington, D.C.: Office of Air Force History, 1990), 13, 15.

[13] Earle, Lark, Parker, Ronning, and Underwood, *Overview of Historic Cultural Resources*, 1998, D-3.

[14] Scott M. Hudlow, Matt Bishoff, Jan Lawson, and John Z. Terreo, *Cultural Resource Evaluation of the North Base Complex (The Muroc Flight Test Base and the Rocket Sled Test Track), Edwards AFB, Kern County, California*, volume 1 (Edwards Flight Test Center: Computer Sciences Corporation, for Air Force Materiel Command, May 1995),132-133.

[15] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 83-85.

[16] Young, Puffer, and Johnson, "The Air Force Flight Test Center," 1996, 11.

[17] Hudlow, Bishoff, Lawson, and Terreo, *Cultural Resource Evaluation of the North Base Complex*, 1995, 142.

[18] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 46.

[19] Hudlow, Bishoff, Lawson, and Terreo, *Cultural Resource Evaluation of the North Base Complex*, 1995, 133-180.

[20] Research and Development Task Force, Office of the Secretary of Defense, *Edwards Air Force Base Data & Information*, 1950, 38-39.

---

[21] Dana McGowan, Susan Lassell, and Shahira Ashkar, *Phase II Cultural Resource Evaluation of the South Base Sled Track at Edwards AFB, Kern and Los Angeles Counties, California* (Sacramento: Jones & Stokes Associates, Inc., for Air Force Materiel Command, May 1998), 15.
[22] Scott M. Hudlow, *Phase II Architectural Evaluation for the Jet Propulsion Laboratory Closure Project, Edwards AFB, Kern County, California* (Edwards Flight Test Center: Computer Sciences Corporation, for Air Force Materiel Command, June 1995), 15-25.
[23] Susan Lassell, Shahira Ashkar, and Dana McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB, California* (Sacramento: Jones & Stokes Associates, Inc., September 1998), 7.
[24] Earle, Lark, Parker, Ronning, and Underwood, *Overview of Historic Cultural Resources*, 1998, 93-95.
[25] *Ibid*, D-3.
[26] Cotterman, Hudlow, Auten, Hurst, Komporlides, and Bupp, *Inventory of Selected Military Period Structures at South Base*, volume 1, 1997, 2-24 – 2-25.
[27] Dena S. Komporlides, Christopher O. Hurst, Linda Auten, Carey D. Cotterman, and Susan L. Bupp, *Historical Overview of the National Advisory Committee for Aeronautics (NACA) and the National Aeronautics and Space Administration (NASA) at Edwards Air Force Base, California* (San Bernardino: Tetra Tech, Inc., for Air Force Materiel Command, February 1996), 2-22.
[28] Earle, Lark, Parker, Ronning, and Underwood, *Overview of Historic Cultural Resources*, 1998, 87, D-3.
[29] Andrew L. York, Tanya Wahoff, and Michael Corbett, *Cultural Resource Investigations at Area P Housing Complex and Adjacent Sites Edwards Air Force Base, California* (San Diego: Dames & Moore, Inc., for Air Force Materiel Command, November 1997), 96ff and inventory forms.
[30] Dena S. Komporlides, Linda Auten, Christopher O. Hurst, Cary D. Cotterman, and Susan L. Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base, Edwards Air Force Base, California*, volume 1 (San Bernardino, California: Tetra Tech, Inc., for Air Force Materiel Command, July 1997), 2-16, 2-18 – 2-19, 2-21.
[31] York, Wahoff, and Corbett, *Cultural Resource Investigations at Area P Housing Complex and Adjacent Sites*, 1997, "P-Area Housing" inventory form.
[32] William Radkovich Co., Inc., "Muroc Army Air Field Temporary Family Quarters," nine drawings for Job No. Muroc AAF 7.210.2, 15 August 1947. One of these drawings may be dated 15 February ("2" not "8"). Also: "Muroc Army Air Field Temporary Family Quarters Topography and General Layout," August 1947, contains an internal reference to specifications W-04-353-Eng-47-31 of 26 March 1947.
[33] William Radkovich Co., Inc., "Muroc Army Air Field Temporary Family Quarters, Floor Plan, Elevations & Details," sheet 4, 12 May 1947.
[34] Air Materiel Command, *History of Muroc Army Air Field 1 July to 31 December 1947*, 36.
[35] Workmen cast each of the two larger units of the houses as monolithic pieces at a single central construction site. Steel boxes comprised the inner house forms. A Tournalayer machine, used for heavy hauling and runway preparations during World War II, positioned the steel boxes for casting. Men next installed the fixtures. They also inserted steel window frames one-inch thick into the walls of the inner house forms, mounting them on temporary steel bucks to fill out the five-inch wall depth until men completed the casting. Next, a Tournalayer lowered an outer box form around the prepared inner house. At the Edwards construction site, a 25-cubic-yard Nobel bin with three-yard hopper, batched pumice aggregate from a nearby stockpile. A Tournamixer received the aggregate and transported the material to the prepared steel boxes (each encased by outer box formwork) for the pouring and casting process. Pours for the body of the house took about 1.5 hours; pours for the smaller living room unit, only 15 minutes. After 16 hours, a Tournalayer picked up each of the monolithic units and hauled them to the individual house sites in Area A. The Tournalayer set each box seven feet from its smaller partner. Workmen added the connecting entry and dining room, and tied the structure together pneumatically with mortar and gunnite.
[36] "On the Job with Tournalayer at Muroc Air Force Base, Lake Muroc, California," *Architectural Record* (104, 2) August 1948: 180, 182; LeTourneau Equipment, *About the LeTourneau On-Site Method of Home Construction* [brochure] (Longview, Texas: R.G. LeTourneau, ca.1947). Accompanied by an introductory letter of 27 August 1947. Held in the Margaret Estes Library, LeTourneau University, Longview, Texas. The *Architectural Record* article contains a good description of the LeTourneau process for house construction at Edwards, as does the *History of Muroc Army Air Field 1 July to 31 December 1947*.
[37] R.G. LeTourneau, Inc., *Low Cost Housing by the Houselayer Form System* (Longview, Texas: R.G. LeTourneau, ca.1949-1950). Held in the Margaret Estes Library, LeTourneau University, Longview, Texas.

---

[38] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 123, 126; "Building 5019," Area A Real Property Cards, Edwards Air Force Base; R.G. LeTourneau, introductory letter for LeTourneau houses, 14 March 1946. LeTourneau material held in the Margaret Estes Library, LeTourneau University, Longview, Texas.
[39] "Area 'A' Housing Improvements Plot & Drainage Plans (Sheet 1)," and, "Area 'A' Housing Improvements Architectural Plans & Elevations," both 1 February 1972.
[40] Based on discussions with the Housing Office on base, April 2000. Exact time period is not researched here, although the information is available in real estate records at Edwards Air Force Base.
[41] Office Chief of Engineers, "Prefabricated Housing for Use Overseas," memorandum to the Chief of Staff, United States Air Force, Installations Engineering Division, 18 August 1948. In Record Group 341, Entry 494, Box 6, File "Housing 1948," 2 of 2, National Archives II, Maryland.
[42] R.G. LeTourneau, Inc., *The Houselayer System: Revolutionary Mass Home-Building Process for Large Scale Low Cost Housing Projects* (Longview, Texas: R.G. LeTourneau, ca.1949-1950). Held in the Margaret Estes Library, LeTourneau University, Longview, Texas.
[43] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 127.
[44] J.D. Lang, Directorate of Installations, United States Air Force, "Procurement of Prefabricated Houses," memorandum, 16 December 1949. In Record Group 341, Entry 494, Box 59, File "Housing Oct-Dec 1949," National Archives II, Maryland.
[45] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 84-92.
[46] Earle, Lark, Parker, Ronning, and Underwood, *Overview of Historic Cultural Resources*, 1998, D-3.
[47] *Ibid*, 93.
[48] McGowan, Lassell, and Ashkar, *Phase II Cultural Resource Evaluation of the South Base Sled Track*, 1998, 10, 12.
[49] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 46-47.
[50] Air Materiel Command, *History of Edwards Air Force Base Muroc, California 1 July – 31 December 1950*, 119-120.
[51] Air Research and Development Command: *History of Air Force Flight Test Center 2 April – 30 June 1951*, 19-20, *History of Air Force Flight Test Center 1 July – 31 December 1951*, 25, and *History of the Air Force Flight Test Center 1 July – 31 December 1952*, 7-8; and, McGowan, Lassell, and Ashkar, *Phase II Cultural Resource Evaluation of the South Base Sled Track*, 1998, 10.
[52] McGowan, Lassell, and Ashkar, *Phase II Cultural Resource Evaluation of the South Base Sled Track*, 1998, 15-48; Earle, Lark, Parker, Ronning, and Underwood, *Overview of Historic Cultural Resources*, 1998, 107.
[53] Young, Puffer, and Johnson, "The Air Force Flight Test Center," 1996, 11.
[54] David A. Anderton, "AF Tests Rocket Engines in Giant Stands," *Aviation Week* 59, 9 (31 August 1953): 24-26.
[55] Irving Stone, "Architect-Engineers Build for Aviation," *Aviation Week* 65, 15 (8 August 1956): 62-69.
[56] Karen J. Weitze, James H. Cleland, Carrie Gregory, and Lori Lilburn, *Historical Assessment of Marshall Space Flight Center*, Draft (San Diego: EDAW, Inc., for the National Aeronautics and Space Administration, May 2002), 49-71, 96.
[57] Lassell, Ahkar, and McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB*, 1998, 13.
[58] Christopher Hurst, Linda Auten, Susan L. Bupp, Cary Cotterman, and Dena S. Komporlides, *Historical Overview of Phillips Laboratory Operating Location at Edwards Air Force Base, California* (San Bernardino, California: Tetra Tech, Inc., for Air Force Materiel Command, July 1997), 4-35.
[59] Hudlow, *Phase II Architectural Evaluation for the Jet Propulsion Laboratory Closure Project*, 1995, 62-92.
[60] *Edwards Air Force Base Data & Information*, 1950, 39.
[61] "Chute Facility Tests Unification," *Aviation Week* 59, 7 (17 August 1953): 411-413.
[62] Air Research and Development Command, *History of the Air Force Flight Test Center 1 January – 30 June 1955*, 132.
[63] *Edwards Air Force Base Data & Information*, 1950, 39.
[64] Air Force Systems Command, "Comprehensive Plan Basic Layout Plan Edwards Air Force Base," 1 February 1963.
[65] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1961*, volume 5, 12.

---

[66] Karen J. Weitze, *Cold War Infrastructure for Air Defense: The Fighter and Command Missions* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 19-78, 138.
[67] *History of the Directorate of Civil Engineering 1 January – 30 June 1961*, volume 5, 12.
[68] Air Force Systems Command, *History of the Air Force Flight Test Center 1 July – 31 December 1963*, volume 1, 44; "Fighter Sqdn Detachment Operational Here," *Desert Wings*, 2 August 1963; Frank Grad & Sons, drawing for Building 1250, 1951; historic photographs of F-106s, Detachment 1, 329th FIS, ca.1963-1967, History Office, Edwards Air Force Base; and, Mueller, *Active Air Force Bases*, 1989, 191.
[69] Komporlides, Auten, Hurst, Cotterman, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base*, 1997, volume 1, *passim*, and, Komporlides, Auten, Hurst, Cotterman, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base*, 1997, volume 2, inventory forms.
[70] "Air Force Housing, Mojave Desert," *Architectural Record* 109, 5 (May 1951): 123-125.
[71] "Concreting the World's Longest Runway," *Engineering News-Record* 152, 12 (25 March 1954): 44-46.
[72] William E. Vaughn, Jr., "Largest Aircraft Testing Base," *The Military Engineer* 49, 329 (May-June 1957): 175-178.
[73] Young, Puffer, and Johnson, "The Air Force Flight Test Center," 1996, 12.
[74] Vaughn, "Largest Aircraft Testing Base," *The Military Engineer*, May-June 1957, 175.
[75] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 41-58.
[76] Komporlides, Auten, Hurst, Cotterman, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base*, 1997, volume 1, 6-18 – 6-21.
[77] "Steel Trussed Arches Span 360 Ft in Hangar," *Engineering News-Record* 157, 6 (9 August 1956): 36-38.
[78] Komporlides, Auten, Hurst, Cotterman, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base*, 1997, volume 1, 6-37– 6-41.
[79] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 19-39.
[80] "Steel Trussed Arches Span 360 Ft in Hangar," *Engineering News-Record*, 9 August 1956. For excellent discussion of the Idlewild Airport hangars see: "World's Largest Steel Arched Hangars," *Architectural Record* 107, 4 (April 1950): 161-164, and, John M. Kyle, "Design Concepts Change at New York International Airport," *Civil Engineering* 25, 11 (November 1955): 58-61.
[81] William Coughlin, "Flight Test Center Probes Aviation's Supersonic Frontiers," *Aviation Week* 59, 7 (17 August 1953): 118-148. Part of an entire issue devoted to Air Research and Development Command, with individual authors and articles on each test installation.
[82] Komporlides, Auten, Hurst, Cotterman, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base*, 1997, volume 1, 6-29 – 6-37. Photographs and descriptions indicate a match for the Kuljian readiness / maintenance hangar of 1955. See Weitze, *Cold War Infrastructure for Air Defense*, 1999, 63-71.
[83] "Extension to Flight Line Security Fence," 7 March 1957.
[84] Komporlides, Auten, Hurst, Cotterman, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base*, 1997, volume 1, 6-4 – 6-54.
[85] Drawings indicate that Aerojet was the firm responsible for the C-5 hangar. However, as a high-profile project discussed within the Directorate of Civil Engineering, the prototypical C-5 hangar is likely the effort of a major Los Angeles architectural-engineering firm working for Aerojet, and more likely still, the product of a firm working closely with the AFBMD on missiles and related test complexes. Evidence suggests that this firm is Ralph M. Parsons.
[86] Headquarters United States Air Force: *History Directorate of Civil Engineering 1 January – 30 June 1966*, volume 3, 23, and, *History Directorate of Civil Engineering 1 July – 31 December 1966*, volume 3, 33.
[87] Headquarters United States Air Force, *History Directorate of Civil Engineering 1 July – 31 December 1967*, volume 3, 21.
[88] *Ibid*, 30, and, Headquarters United States Air Force, *History Directorate of Civil Engineering 1 July – 31 December 1968*, volume 3, 32.
[89] Headquarters United States Air Force, *History Directorate of Civil Engineering 1 January – 30 June 1971*, volume 3, part 1, 63.
[90] Historical discussion of the development, flight testing, and production of the C-5, posted at www.csd.uwo.ca. See also, Komporlides, Auten, Hurst, Cotterman, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base*, 1997, volume 1, 6-25 – 6-29.

[91] Lassell, Ahkar, and McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB*, 1998, 39-41.
[92] Wright Air Development Center, *User's Manual United States Air Force SMART Track*, undated (ca.1955); Coleman Engineering Company, Inc., *The Fact Book of Project SMART*, undated (ca.1958); and, McGowan, Lassell, and Ashkar, *Phase II Cultural Resource Evaluation of the South Base Sled Track*, 1998, 10-12. The author has not determined whether the test track on Hurricane Mesa exists today, either intact or in remnants.
[93] Young, Puffer, and Johnson, "The Air Force Flight Test Center," 1996, 22.
[94] Komporlides, Auten, Hurst, Cotterman, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at Main Base*, 1997, volume 1, 6-54 – 6-63.
[95] "North American X-15," posted at users.dbscorp.net/jmustain/x15.htm. A scramjet scoops oxygen directly from the air and alleviates the interference of the engine's compressor fan above Mach 3. For subsonic flight, an attached ram jet compresses the air through the forward speed of the aircraft for an improved performance by "ram" effect. A ram jet does not work above Mach 6.
[96] "X-15 and Starlet," *The Marshall Star* 2, 8 (15 November 1961): 7.
[97] Warren E. Leary, "Test of Revolutionary Jet Promises to Transform Flight, *New York Times*, 22 May 2001, and "Errant Rocket Dooms Trial of New Jet in NASA Test," *New York Times*, 3 June 2001. Also see: "Air-breathing jet flies at 5,000 mph" and "Hypersonic Jet Launch Raises Hopes," posted at www.freerepublic.com/focus/news/734597/posts and www.freerepublic.com/focus/news/724624/posts, respectively.
[98] Hurst, Auten, Bupp, Cotterman, and Komporlides, *Historical Overview of Phillips Laboratory*, 1997, 4-35, 4-40 – 4-43.
[99] *Ibid*, 6-1ff; Lassell, Ahkar, and McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB*, 1998, 51-52, 57-58.
[100] Hudlow, *Phase II Architectural Evaluation for the Jet Propulsion Laboratory Closure Project*, 1995, 93-122.
[101] Lassell, Ahkar, and McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB*, 1998, 61-62, inventory forms for Test Area 1-100.
[102] Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, 1990, 177, 187, 192-194.
[103] John C. Lonnquest and David F. Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program*, USACERL Special Report 97/01 (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, November 1996), 311.
[104] Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, 1990, 228-230.
[105] Lonnquest and Winkler, *To Defend and Deter*, 1996, 245-246, 311.
[106] Helen Rice, *History of Ogden Air Materiel Area 1934 – 1960*, volume 1 (Hill Air Force Base: Office of Information, Air Force Logistics Command, March 1963), 217.
[107] Lonnquest and Winkler, *To Defend and Deter*, 1996, 245-246.
[108] Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, 1990, 215, 218.
[109] Lonnquest and Winkler, *To Defend and Deter*, 1996, 246.
[110] Frederick J. Shaw, Jr., and Timothy Warnock, *The Cold War and Beyond: Chronology of the United States Air Force, 1947-1997* (Washington, D.C.: Air Force History and Museums Program in association with Air University Press, 1997), 37.
[111] Lassell, Ahkar, and McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB*, 1998, 61.
[112] Weitze, Cleland, Gregory, and Lilburn, *Historical Assessment of Marshall Space Flight Center*, 2002, inventory forms for Buildings 4670 and 4696.
[113] Lassell, Ahkar, and McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB*, 1998, 45ff.
[114] Hudlow, *Phase II Architectural Evaluation for the Jet Propulsion Laboratory Closure Project*, 1995, 122-141.
[115] Earle, Lark, Parker, Ronning, and Underwood, *Overview of Historic Cultural Resources*, 1998, D-4 – D-5.
[116] Cotterman, Hudlow, Auten, Hurst, Komporlides, and Bupp, *Inventory and Evaluation of Selected Military Period Structures at South Base*, volume 1, 1997, 6-2 – 6-59. Individual inventory forms comprise volume 2.
[117] Arthur Kuljian, *Kuljian Airport Planning, Design and Engineering*, binder of company brochures, job lists, and journal offprints, compiled in March 1999 for an interview with Karen J. Weitze.

[118] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 41-48.
[119] R.G. LeTourneau, Inc., *The Carefree Home* (Peoria, Illinois: R.G. LeTourneau, Inc., 1937 or 1938). Held in the Margaret Estes Library, LeTourneau University, Longview, Texas.
[120] LeTourneau Company of Georgia, Steel Buildings Division, *More Modern Buildings Constructed of Steel* [brochure] (Toccoa, Georgia: R.G. LeTourneau, 16 September 1940). Held in the Margaret Estes Library, LeTourneau University, Longview, Texas.
[121] "LeTourneau R(obert) G(ilmour)," entry in *Current Biography*, 1958, 244-245. Excerpt held in the Margaret Estes Library, LeTourneau University, Longview, Texas.
[122] *Ibid.*
[123] Stone, "Architect-Engineers Build for Aviation," *Aviation Week*, 8 August 1956, 64; Weitze, Cleland, Gregory, and Lilburn, *Historical Assessment of Marshall Space Flight Center*, 2002, 49; and, information posted at www.parsons.com/govt/defense/index.
[124] "Architect-Engineer Services for Air Force Work Furnished by Pereira and Luckman," memorandum for the Under Secretary of the Air Force from the Directorate of Construction, Assistant Chief of Staff, Installations, 20 December 1954, in File "A&E Contracts Nov-Dec 1954," Box 496, Entry 494, Record Group 341, National Archives II.
[125] David Gebhard and Robert Winter: *A Guide to Architecture in Los Angeles & Southern California* (Santa Barbara and Salt Lake City: Peregrine Smith, Inc., 1977), and, *Architecture in Los Angeles* (Salt Lake City: Gibbs M. Smith, Inc., 1985); and, David Gebhard, Roger Montgomery, Robert Winter, John Woodbridge, and Sally Woodbridge, *A Guide to Architecture in San Francisco & Northern California* (Santa Barbara and Salt Lake City: Peregrine Smith, Inc., 1973).

Chapter 4: Eglin Air Force Base

Historic Missions of the Cold War

During the period of 1945 to 1991, Eglin Air Force Base served as the proving ground for the Air Force, as well as its armament test center. The Army Air Forces / Air Force assigned Eglin to two commands to fulfill these roles. At the outset of the Cold War, Army Air Forces Proving Ground Command / Air Proving Ground Command managed the base. Headquarters United States Air Force next assigned Eglin to Air Materiel Command for the first six months of 1948, but followed this command structure by a return to Air Proving Ground / Air Proving Ground Command between June 1948 and late 1957. The armament test mission continued at the installation under Air Materiel Command (and subsequently, Air Research and Development Command [ARDC]) without a lapse: in 1948-1949, as the Armament Development and Test Center, and between December 1949 and February 1958 as the Air Materiel Armament Test Center. The proving ground and armament test missions at Eglin were intertwined, and as of December 1957, Headquarters Air Force formally integrated them in two ways. Headquarters Air Force combined the Air Proving Ground with the Armament Test Center as the Air Proving Ground Center and simultaneously placed Eglin under the jurisdiction of the research and development (R&D) command—at this date, ARDC. From this point forward, Eglin fell under ARDC and its follow-on commands, Air Force Systems Command (AFSC) and Air Force Materiel Command. The installation has sustained a proving ground mission for aircraft, weapons systems, and related support equipment (such as radar) throughout its history, with a specialized focus on armament testing.[1] Eglin's associated ranges cover more than 700 square miles, with 10 auxiliary airfields in place from World War II. The ranges and test areas varied from large to small in their boundaries, and included the barrier island of Santa Rosa along the coast of the Gulf of Mexico and the overwater Eglin Gulf Test Range (EGTR). The ranges accommodated a wide variety of research and development efforts, as well as progressive levels of testing and evaluation. The ranges also functioned as training locations for not only the Air Force, but also for the Army and the Navy at particular auxiliary airfields. Infrastructure on Eglin's ranges featured targets and test structures erected continuously, with temporal and spatial components overlapping at some sites, and multiple instances of reuse. The installation was additionally a major Air Force test location for theater-of-war infrastructure and personnel training during the protracted Vietnam War. Throughout the Cold War, Eglin Air Force Base also supported selected specialty missions of ARDC / AFSC, as well as hosting key tenant missions for Air Defense Command (ADC), Strategic Air Command (SAC), Tactical Air Command (TAC), Space Command / Air Force Space Command (AFSPC), and the National Aeronautical and Space Administration (NASA).

Primary Missions

The primary Cold War missions of ARDC / AFSC at Eglin Air Force Base were:

- armament testing, including aircraft;
- cold weather testing in the climatic hangar;
- ground instrumentation, electronics, and radar testing;
- guided missiles testing and squadron training;
- high-altitude sounding rocket testing;
- biochemical weapons systems testing;
- nuclear weapons testing;
- jungle warfare test and training;
- development of protective construction, including the extended aircraft shelters program (in conjunction with efforts at Kirtland Air Force Base in New Mexico and Hill Air Force Base in Utah);

- testing for prefabricated and mobilization infrastructure;
- development and testing of runway surfacing and runway rapid-repair kits for wartime conditions; and,
- design and development of range target infrastructure.

Tenant Organization Missions

Key tenant missions of other Air Force commands hosted at Eglin were:

- SAC alert during the late 1950s into the middle 1960s;
- sponsorship of the ADC large phased-array radar prototype in the 1960s (as a part of a major program of radar developmental testing run at Eglin by the Rome Air Development Center of ARDC / AFSC), subsequently an operational Space Command / AFSPC facility; and,
- multiple TAC missions throughout the Cold War, including advisory training for the Vietnam War, fighter aircraft alert, and Blue and Green Flag exercises.

NASA also had a significant mission at Eglin during the 1959-1972 period:

- experimental and information-gathering high-altitude test packages, launched from the vertical probe site on Santa Rosa Island.

Army and Navy missions at Eglin are broadly referenced below in the chronological discussion of installation Cold War history. Examples of several major missions of the sister services included:

- the Army Ranger jungle warfare training and Chemical Corps classified testing at Field 7 from the early 1950s into the 1960s;
- the Army's Ranger Camp at Field 6 (an exclusive tenant at the location as of 1970 and still in place in 2003);
- Navy pilot training at Field 10 abutting the Naval installation at Pensacola beginning in the early 1950s; and,
- the Navy's training center for explosive ordnance disposal (EOD) on Range 51 (Test Area D-51).

Chronology

Eglin dates to 1931, when officers from the Air Corps Tactical School at Maxwell Field in Montgomery, Alabama, began vacationing along the Gulf of Mexico in the Florida panhandle and simultaneously initiated considerations for a gunnery and bombing range in the area of Valparaiso.[2] The Air Corps additionally sought a proving ground for testing aircraft, equipment, and armament, and for running operational trials. A local businessman, James E. Plew, hastily developed the Valparaiso Airport by the middle 1930s, leasing the facilities to the Air Corps for a nominal fee. Paralleling these activities, the Air Corps built a recreational camp for officers at nearby White Point on Choctawhatchee Bay. As of mid-1935, the Air Corps had 15 men stationed at Valparaiso, with construction of barracks, support buildings, and runway extensions underway by autumn. By the next year, Army personnel at Valparaiso climbed to 360 men. In March 1937, the United States Attorney General formally approved the legal transfer of the 1,460 acres of Valparaiso Airport to the federal government. In August, the Air Corps renamed the installation Eglin Field, in honor of Lieutenant Colonel Frederick I. Eglin of the Air Corps Tactical School. The Army designated Eglin as a subpost of Maxwell Field, and buildup of facilities on site continued.

Almost immediately after christening as Eglin Field, events shaping the installation became more complicated. The Air Corps, including representatives from both Maxwell and Wright Fields, desired to establish an armament proving ground in the United States. As of 1939, the Air Corps evaluated several possible sites for this mission:

- the Aberdeen Proving Ground (Edgewood Arsenal) assigned to the Chemical Warfare Service in Maryland;
- an area near Oscoda, Michigan (the site of the later Wurtsmith Air Force Base);
- Ogden, Utah (the site of the later Hill Air Force Base and its Utah Test and Training Range [UTTR], as well as in the vicinity of what would shortly become the Dugway Proving Ground of the Chemical Warfare Service); and,
- Forts Benning, Bragg, and Knox in the Southeast.

The Netherwood Committee handled the review process and elected to overrule these choices, instead suggesting Eglin. The Chemical Warfare Service at Edgewood, where the Army had hitherto developed much of its specialized ordnance, also approved the Eglin site. The Air Corps next gave Eglin Field responsibility for selected bomb and aerial armament testing and evaluation previously undertaken at Edgewood / Aberdeen. In late June 1940, the emerging proving ground grew by 383,956 acres, with land transferred to the War Department from the Choctawhatchee National Forest adjacent to Eglin. Major construction at Eglin Field moved forward during 1940 and 1941. During this era, many of the buildings were 700- and 800-series, woodframe temporaries, with the overall building program distinguished from those at other Army installations through adaptation in the cantonment area for the warm, tropical climate of the Gulf Coast.

During late 1941, the Air Corps formally designated Eglin Field the Air Corps Proving Ground (as of April 1942, the Army Air Forces Proving Ground). The World War II installation included 10 numbered and named airfields in addition to that of the main base: Field 1 (Wagner), Field 2 (Pierce), Field 3 (Duke), Field 4 (Peel), Field 5 (Piccolo), Field 6 (Biancur), Field 7 (Epler), Field 8 (Baldseifen), Field 9 (Hurlburt), and Field 10 (Dillon) (Plate 44). The Army Air Forces used the auxiliary airfields as single-engine, gunnery training airdomes, with the exceptions of Fields 1, 8, and 9. Field 1 served as a site for extra-hazardous testing as of mid-1945, while Field 8 was the Proof Department field. Field 8 was associated with Range 52 for major bombing tests. The Army Air Forces developed Field 9, Hurlburt Field, much more extensively than the other fields, with a full-scale permanent cantonment. Hurlburt served as an electronics proving ground and later as a major TAC enclave, with activation of electronics and countermeasures sections in early 1943. Key infrastructure at Eglin's main base included an armament laboratory, hangars, ground gunnery range, torpedo shop, high-altitude test building (strato-chamber), and the Arctic, Desert, and Tropic Information Center. The climatic hangar was under construction during 1944-1945, and represented a bridge between the severe cold-weather testing mission originating during World War II and that of the Cold War. World War II ranges at Eglin numbered 1 to 67, with an additional Crossbow Range. Ranges 64, 65, and 66, from the end of the war, were also the first to feature identifiable Cold War missions. As of mid-1942, Army personnel at Eglin numbered about 6,400. Fifty-five percent of the men stationed at the base were black.

During the early Cold War, the auxiliary fields acquired more distinct missions, with some Army and Navy use. At the outset of 1951, the commander of the Air Proving Ground, General Bryant L. Boatner, described Eglin's assets as Balkanized—a direct reference to the splintered, ethnic enclaves in Soviet eastern Europe. A battalion of Aviation Engineers had full use of Field 1, with Continental Air Command requesting the field (and 6,000 surrounding acres) for its sole occupation. TAC occupied Field 2; two Air Proving Ground drone squadrons had Field 3; and, ADC used Field 6. The

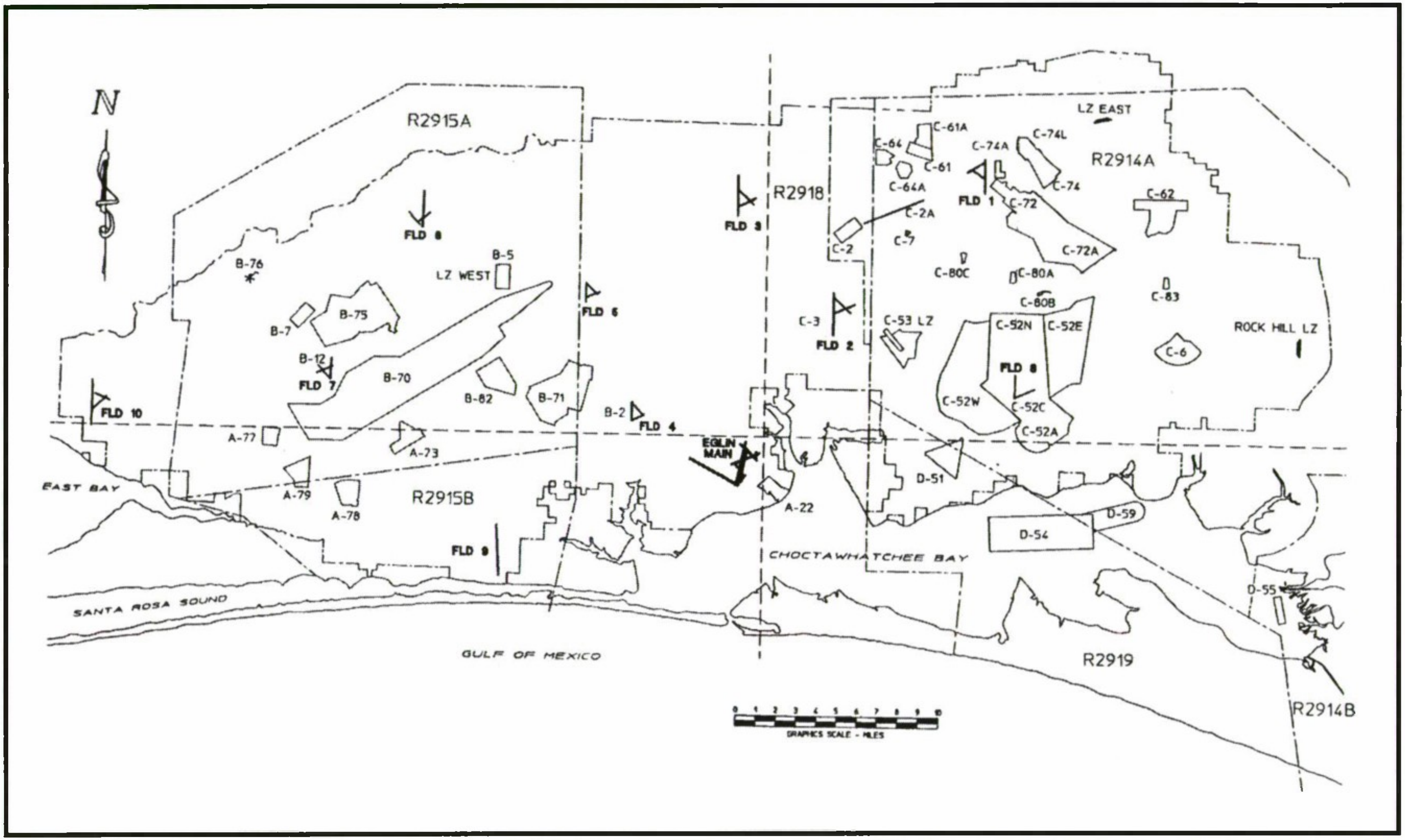

Plate 44: Eglin Air Force Base Auxiliary Fields and Test Ranges. In *Land Test Areas*, volume II of *AFDTC Technical Facilities*, July 1996.

Army Chemical Corps shared Field 7 with the Air Proving Ground for classified testing. Following the Korean War, Field 7 also hosted Army Ranger amphibious and jungle troop training for the Infantry School at Fort Benning, Georgia. Field 7 then transitioned to exclusive Army Ranger use. The Air Force planned for Field 9 to support an Air Training Command fighter-bomber combat crew training school. ADC later occupied this auxiliary field for an surface-to-air missile mission after a move from Field 6. TAC's Field 2 evolved as a reserves training location in the 1950s, and as the Eglin Electronic Warfare Test Sector (complementing World War II efforts at Field 9). Field 4 developed during the 1950s as the mission area for aerial targets and scorers, and also served as a tow target drop site along with Field 5. The Navy fully controlled Field 10, neighboring its installation at Pensacola, for pilot training from its beginnings until 1960. The Army and Navy also each established activities at Field 6.[3]

The earliest Cold War missions at Eglin Air Force Base have critical roots in endeavors of World War II, with perhaps the very first of these the mission for cold-weather testing. In November 1941, Lieutenant Colonel Frank Carroll, Chief of the Experimental Engineering office for Air Materiel Command at Wright Field, had assigned Ashley C. McKinley the task of studying cold-weather aircraft and equipment improvements. McKinley, possessing considerable experience in Antarctica during 1928-1930, concluded that the Air Corps' efforts had been chaotic, and that testing in the continental United States did not allow sufficiently low or reliable temperatures. Typically, aeronautical engineers had geared experimentation toward winters in Dayton, not extreme conditions, with the "small inefficient cold room [at Wright Field] used almost exclusively by the Medical Department." McKinley toured Alaskan airfields during January to March 1942. The Cold Weather Testing Detachment from Wright Field had run tests since 1940 at Ladd Field near Fairbanks, coordinating its efforts with the Cold Weather Liaison Office at Wright Field managed by McKinley. The winter of 1942-1943 was so severe that the implications of successful flying in extreme cold weather were thrown into high relief. Air Materiel Command discovered, however, that Alaska's cold weather periods were also not entirely predictable and realized by early 1943 that controlled conditions were a necessity. By this date, Eglin's Arctic, Desert, and Tropic Information Center was already gathering and evaluating scientific data on extreme climates of possible concern to the Army Air Forces. Air Materiel Command sustained the Information Center at Eglin through late October 1943, then moved it to New York until definite plans for a controlled test chamber emerged in April 1944. The command subsequently returned the Information Center to Eglin, an event that presaged the arrival of the climatic hangar at the base immediately post World War II.

McKinley recommended a refrigerated proof testing facility capable of sustaining strictly controlled conditions. Proof tests at Eglin had numbered in the thousands during World War II. The Army Air Forces tested everything from new and improved aircraft and weapons systems, to Nestle's and Hershey's chocolate bars as quick-energy food for pilots at high altitude. The tests were of operational suitability type, run at four numbered category levels. During the Cold War, proof testing continued, generally referenced as progressive "Category I, II, III, or IV" tests of particular items.[4] For cold-weather proofing, McKinley's studies had indicated that a temperature of –65 degrees Fahrenheit (F) was the critical benchmark. As early as January-February 1944, McKinley argued for a cold hangar at Eglin. As the project evolved, design and engineering for the hangar shifted to include not just severe cold weather, but also all extreme weather conditions. By mid-1944, Robert & Company in Atlanta contracted for the hangar (Building 440). Costs escalated for the complex structure from $1.5 million at the outset of the project in 1944, to a final cost of about $5.6 million by mid-1946 (Plate 45). The Army Air Forces required that the hangar allow testing of the B-36, which was a much larger aircraft than the B (bomber) -29 and was one not yet flying. As built, the climatic hangar accommodated tests within a –70F to 165F-degree range. (Today the lower temperature range can reach –105F degrees.) The climatic hangar achieved the drop to –70 degrees F in under 48 hours, with the capability of sustaining a soaking period of 24 hours at that temperature. To attain the high

temperatures for desert and tropic tests, the hangar heated from 25 to 165 degrees F in 16 hours, with humidity also controlled at values between 10 and 95 percent. To support the B-36, engineers designed the floor to a thickness of 34 inches. Insulation built into the walls and ceiling featured interior and exterior vapor barriers, air spaces, and 13 inches of fiberglass. The size of the hangar only barely accommodated the B-36, at 250 feet wide by 200 feet long with a 200-foot-wide door. Air Proving Ground Command ran its first operational test on aircraft in the climatic hangar in May 1947, following preliminary tests during the first months of the year. These Arctic tests included the B-29 bomber; P (pursuit) -47, P-51, and P-80 fighters; and, the R (rotary wing) -5D helicopter. In late 1947, under an Air Materiel Command directive, the Air Proving Ground initiated low-temperature proof testing for the B-36A. The command continued tests for the B36-A into 1949. Eglin's climatic hangar accommodated the entire B-36 in an enclosed, controlled space. Eglin's test personnel also analyzed equipment behavior in the hangar, as well as that of small, full-scale structures. During the early climatic tests, the Air Force often duplicated efforts in the hangar through outdoors testing up at Ladd Air Force Base in Fairbanks. One example was a 1950 test of a fiberglass nose dock for the F (fighter) -80. Air Materiel Command intended that the nose dock partially house the fighter aircraft on alert in extreme cold-weather conditions (Plate 46). The climatic hangar was easily the most important proof test facility at Eglin during the late 1940s, one that would remain of consistently high value in the decades that followed. Cold weather testing, in particular, became newly scientific. Not only did the Air Force use the controlled environment, but aircraft manufacturers, industrial firms, and other military service arms did so as well. Testers were able to probe theoretical concepts of refrigeration and insulation in ways not possible in the past.[5]

A second early Cold War mission at Eglin of major stature was that for the JB (jet bomb) -2 guided missile. The JB-2 derived from the German V ("vengeance" / Vereinigung) –1. In autumn 1944, Eglin assigned the weapon its own test range on Santa Rosa Island (Range 64)[6] (Plate 47). The year before, in January, General Henry H. "Hap" Arnold had ordered the Air Proving Ground to construct a mock-up of a V-1 launch site, and then determine the most efficient way to destroy it. The Army Air Forces named the mock V-1 launch site the Crossbow target (coded "C" on period maps, to the northeast of Range 52). The target foreshadowed the launch site for the JB-2 on Santa Rosa (Buildings 9200-9261, with some later additions for general range instrumentation).[7] First JB-2 launch efforts used a 50-foot inclined trailer ramp devised at Eglin and built from steel railroad track. Testers tried various fuel combinations for the experimental JB-2 launchings. Soon after, Air Materiel Command provided the Air Proving Ground with an actual V-1 ramp shipped from France. Testers erected this ramp alongside the first structure. They next augmented the JB-2 program by commissioning the American Bridge Company to replicate the captured German ramp, improving it with certain structural modifications. Eglin personnel configured the two final JB-2 launch ramps on Range 64 as three-degree, steel structures supported by 13 pairs of reinforced concrete pillars, with an approximate length of 350 feet each. A third area for the JB-2 on Range 64 featured two reinforced concrete slabs poured for portable launchers. Also at Eglin, the Army Air Forces air-launched the first JB-2 from a B-17 in March 1945. Test launches continued into August, with over 200 JB-2s fired at Eglin. At the end of the war in the Pacific, three Eglin officers representing a JB-2 squadron went to the Philippines to discuss deployment of the JB-2 against Japan. While the dropping of two atomic bombs abruptly ended the war, the JB-2 test program at Eglin demobilized only briefly. General Orders created the 1st Experimental Guided Missiles Group on 25 January 1946, with the World War II JB-2 launch site on Santa Rosa Island significantly expanded. The JB-2 program at Eglin included tests of other models of the guided missile, with tests originating through Air Materiel Command at Wright Field. In at least the case of the JB-3, the command combined its efforts with those of the National Advisory Committee for Aeronautics (NACA). The 1st Experimental Guided Missiles Group used stockpiled JB-2s for tests of guidance, radar, camera, phototheodolite, and target seeker equipment; for targets; and, for demonstrations. Launches continued at Eglin, and at the Wendover Bombing Range in Utah, shifting from Wendover to

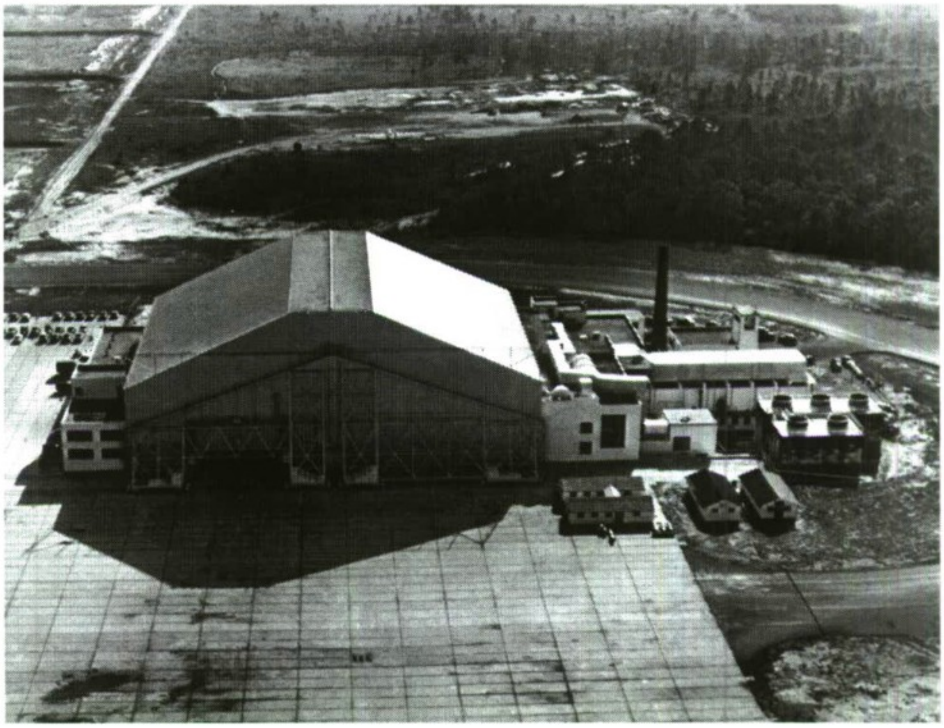

Plate 45: Robert & Company. Climatic Hangar (Building 440), Eglin Field, near completion in early 1946. In *Air Proving Ground Historical Data 2 September 1945 – 30 June 1949*, volume 4.

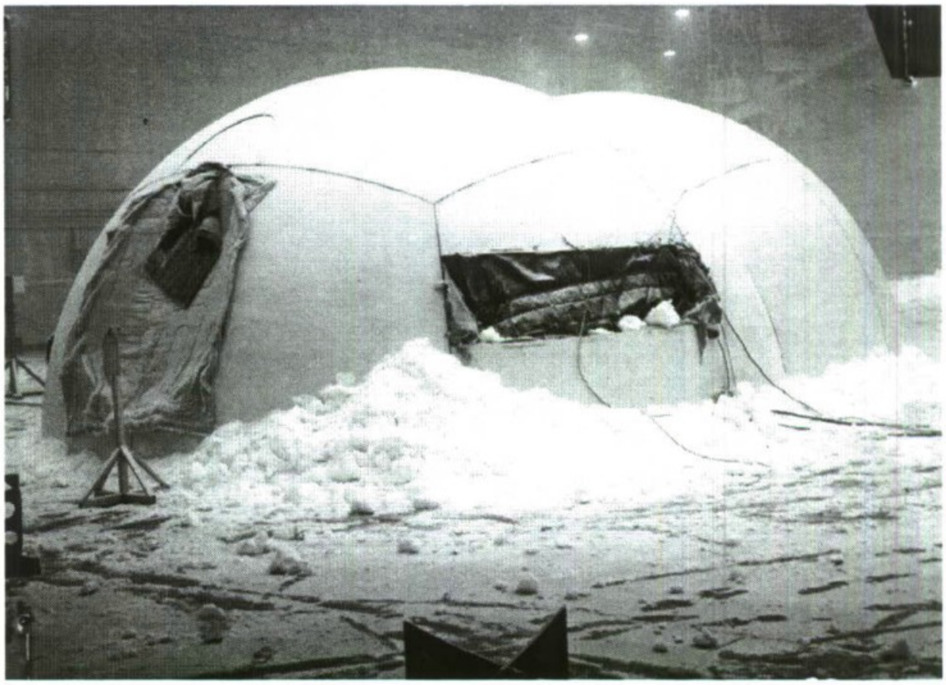

Plate 46: F-80 Double-Igloo Nose Dock. Undergoing heating test in the climatic hangar, Eglin Air Force Base, 10 October 1950. In *3200 Proof Test Group History 1 July – 31 December 1950.*

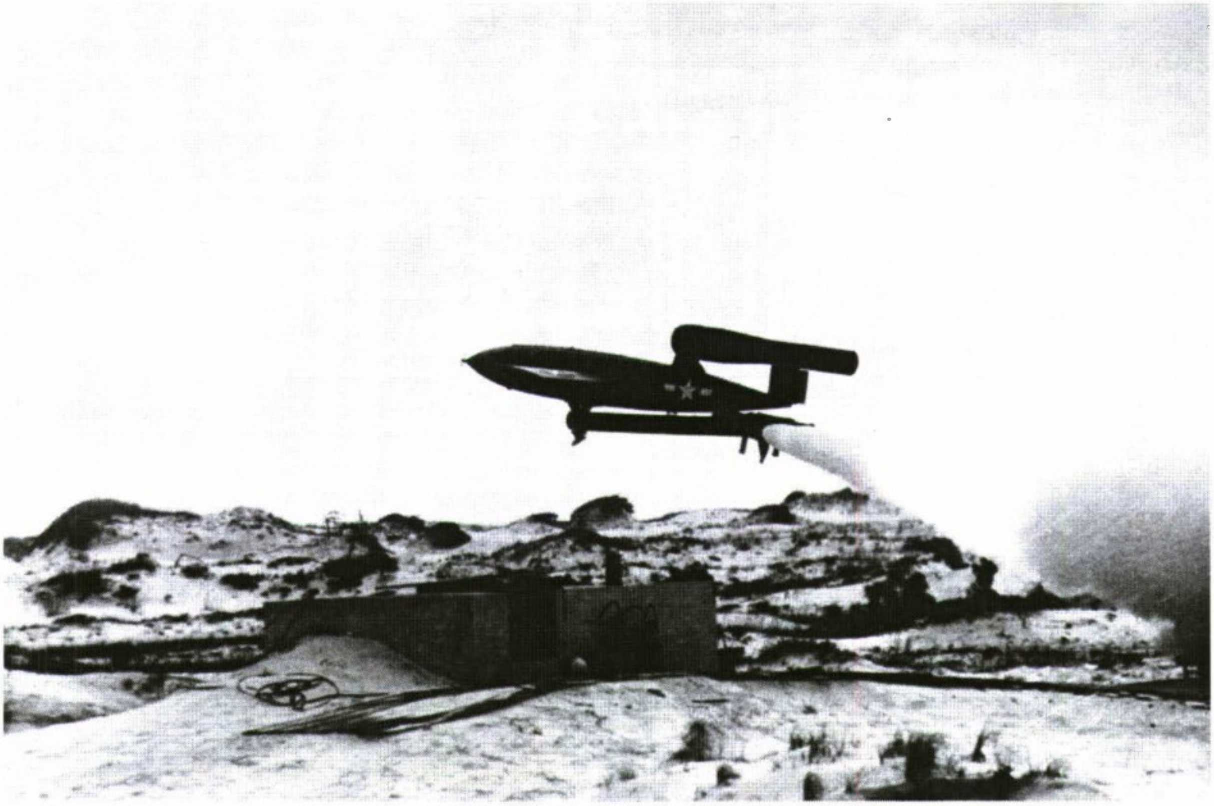

Plate 47: JB-2 Launch, Santa Rosa Island, Eglin Field, ca.1945. Prior to dropping rocket sled. In *Air Proving Ground Historical Data 2 September 1945 – 30 June 1949*, volume 4.

Alamogordo Army Air Field (later renamed Holloman Air Force Base) in New Mexico during late 1947. JB-2 launches by the 1st Experimental Guided Missiles Group stopped at Eglin in late 1949, with a demonstration air launch in October, although both air and ground launches continued through the brief-lived 1st Guided Missiles Squadron and 2nd Guided Missiles Squadron, respectively.[8]

The third early Cold War achievement at Eglin that extended back into the late years of World War II was the design and engineering for a nose dock large enough to accommodate maintenance on the B-36 (Building 110). While the climatic hangar of 1944-1946 had evolved through refinements during construction to allow entry and egress of the B-36, its adaptation had been marginal for the huge 300,000-pound bomber. Preparation for armament and cold-weather testing of the B-36 at Eglin also required major runway improvements, from extensive substructure, to lengthening and widening for the bomber's take-off and landing. Testing for the B-36 was an urgent early Cold War mission, with the "very, very heavy bomber" (VVHB) highly favored by SAC commander General Curtis E. LeMay. The War Department authorized reconstruction of the primary north-south Eglin runway for the B-36 in June 1945. Engineers lengthened the runway from 6,000 to 10,000 feet, with widening from 150 to 300 feet. The B-36 upgrade at the end of World War II included a maintenance hangar for the bomber, with the infrastructural package planned at $5 million. The Army Air Forces hired engineer Fred N. Severud of New York to design the hangar. Severud designed an expansible nose dock, drawing upon his 1941 revisions to a transport squadron hangar designed by Albert Kahn for Air Materiel Command. The Severud B-36 nose dock at Eglin was the first true hangar designed and engineered for the Cold War. While the nose dock did have several mates in California, at the

San Bernardino Air Materiel Depot (San Bernardino Army Air Field, later Norton Air Force Base) and Fairfield-Suisun Army Air Field (later, Travis Air Force Base), the hangar captured an important transitional moment in planning for the B-36 and is exceptionally rare (see Volume I, Part II and Volume I, Plates 5 and 6).[9]

In mid-1945, at the time of the design of the B-36 nose dock at Eglin, the bomber was still not even an experimentally ready aircraft. Severud's hangar was 120 feet deep, by nearly 324 feet wide. The B-36's 162-foot length, 230-foot wing span, and 49-foot height fit into the hangar with the tail of the bomber protruding (hence the hangar's true configuration as a nose dock). The nose of the B-36 was 50 feet long, appropriate to the rear 60 feet of the dock, while allowing vertical support for the center beam without interference from the bomber's wings. The front cantilevered 60 feet of space accommodated part of the body of the aircraft and the wings, which left a little over 90 feet of working room at the sides of the bomber for maintenance platforms, and for maneuvering the B-36 in and out of the hangar. Severud's hangar was expansible to the side, with the initial intention to double the capacity of the structure for two B-36s at one time. The basic expanded footprint of the hangar would have measured about 650 feet across. Convair (Consolidated Vultee) delivered the first production version of the B-36 (the B-36A) to SAC in 1947, the year the Severud nose dock became operational and testing began in the climatic hangar. The period was exceptionally fluid for the design of infrastructure for the bomber. While SAC did not choose the Severud nose dock for its basewide B-36 permanent maintenance structure, the command also aborted plans for buildout of the subsequent B-36 hangar—a thin-shell, ribless hangar designed by Anton Tedesko of Roberts & Schaefer in May 1947 (see Volume II, Chapter 14 and Volume II, Plate 193). As was the case for the Severud nose dock, the Air Force completed only two Tedesko hangars, turning to a final large-hangar solution in the Kuljian double-cantilever hangar of 1951 (see Volume I, Part IV and Plate 112; also, Volume II, Chapter 3 and Plates 34, 111, and 133). Of note, both Severud and Tedesko were emigrant engineers of international prominence[10] (see Volume I, Parts II and III).

Eglin's new Cold War missions of the late 1940s focused on armament evaluation and testing. While the installation had constructed targets on Range 65 (developed during 1944-1945) for bombardment of heavy reinforced concrete infrastructure, the efforts there ended in 1947. Range 65 featured a one-third scale submarine pen target, as well as a concrete penetration wall 145 feet long and 37 feet tall. To date, research information on the submarine pen is not fully conclusive, although the likelihood is that the test structure related to a specific project of the Army Air Forces or of the National Defense Research Committee (NDRC) late in the war. For the test wall, the Army Air Forces intended to include impact tests against the structure from the Navy's high velocity aircraft rocket (HVAR) Tiny Tim, as well as tests from other experimental HVARs. (As carried out, the Navy tested the very powerful Tiny Tim, an 11.75-inch diameter rocket and the largest Allied air-launched HVAR of the World War II years, at its Inyokern range at China Lake, California, in August 1944.) American and British Air Forces had joint interests in achieving effective penetration of the reinforced-concrete construction that protected not only German bunkers, but also a variety of industrial manufacturing sites and the Nazi submarine pens. The Air Proving Ground had run traditional bombardment tests against mock German construction at both Eglin and the Aberdeen Proving Ground in Maryland as of 1943-1944. Tests in Maryland used Army and Navy bombs in the 1,000- to 2,000-pound category, with the conclusion that a much heavier bomb was needed to affect protective German construction. The 1,000- and 2,000-pound bombs were partially an NDRC project, typically referenced among the service arms as vertical bombs (VBs). The VB-1 and VB-3 were both 1,000-pound bombs, while the VB-2 was a 2,000-pound bomb. Bombardiers could partially control the drop of VBs, with the VB-1 (Azon [<u>az</u>imuth <u>on</u>ly]) and the VB-2 (Razon [<u>r</u>ange and <u>az</u>imuth <u>on</u>ly]) both successful weapons of 1944 and 1945. Eglin participated in VB tests, with VB-1 and VB-2 tests run at the Tonopah Bombing Range in Nevada (later, the Nellis Air Force Range attached to Nellis Air Force Base) and at the Wendover Bombing Range in Utah (later partly ceded to the Dugway Proving Ground and

partly absorbed into the UTTR). Eglin started tests for the VB-3, a post-war 3,000-pound bomb, on targets erected at the Ocala Bombing Range in central Florida in late June 1945.[11]

The British Royal Air Force (RAF) and the American Army Air Forces had been unsuccessful in destroying the protective construction of German pillboxes, underground plants, and submarine pens late in World War II—leading immediately to Project Ruby in 1946. Ruby, alternately called the Anglo-American Large Bomb Project, followed aerial bombing at the war's end and used 12,000- and 20,000-pound Tall Boy and Grand Slam bombs. Immediately after VE (Victory in Europe) day, in June 1945, the RAF continued to bomb German industrial structures, beginning with the V-1 launch complex at Watten. The American Army, for its part, collected information for the engineering of such buildings through the Joint Intelligence Objectives Agency. The RAF concluded that the selected Watten complex was too small to test its newest large bombs. They desired to test against the German submarine assembly plant near the village of Farge, 14 miles northwest of Bremen on the Weser River in the American-held sector of Germany. The RAF invited the Army Air Forces to join its project, and representatives of the two armed forces met in London in September. The Army Air Forces first assisted the British by dropping its Disney bomb, a 4,500-pound, rocket-assisted munition, using American B-17s. Project Ruby was the next phase of the joint British-American effort: a self-sustained detachment, consisting of crews, technicians, maintenance men, and aircraft assigned to the Air Proving Ground at Eglin and outfitted for six months overseas. Ruby was underway in spring 1946, outfitted with four B-17s and three B-29s. Test loading the British Tall Boy had occurred at Eglin. The project flew 126 bombing missions against submarine targets at Farge (an assembly plant) and Heligoland (pens) between late March and mid-July 1946. Eglin's bombers dropped over 625 tons of munitions. The American 22,000-pound bomb, the Amazon, was also included in the tests. None of the bombs penetrated the 23-foot, reinforced concrete roof of the Farge plant, and while destruction of the 10-foot roof at Heligoland was significantly better, the overall project highlighted a need to improve both future bombs and a proto-hardened construction to protect against an enemy's similar munitions. Even the very large Amazon could penetrate only about 15 to 16 feet of heavily reinforced concrete. Project Ruby immediately led to new munitions and protective construction research by the British and Americans. At the Roads Research Laboratory in London, specialists focused on the "anti-concrete" bomb. In the United States, the Army-Navy Munitions Board (ANMB) set up the Underground Sites Committee to explore the development of munitions storage and manufacturing capabilities below ground (see Volume I, Part III). During 1947 also, efforts begun through Project Ruby continued as Project Harken. Sponsored by SAC and overseen by General LeMay, Harken ran about four months, with practice bombing at Muroc Lake, California (at the future Edwards Air Force Base) and strategic bombing in Germany (from an occupied installation in Giebelstadt).[12]

Beginning in early 1948 and continuing into the early 1950s, Eglin Air Force Base (and the Air Proving Ground) underwent formal name and command assignment changes moving toward its establishment as a full-fledged armament test installation. In January, the Air Force assigned the Air Proving Ground to Air Materiel Command (from Air Proving Ground Command), with a shift in names to the Air Materiel Proving Ground. The installation name remained consistent as Eglin Air Force Base. The command designation did not immediately alter the emphasis on proof testing at Eglin, but did solidify the base's direct links to the armament research, development, testing, and evaluation mission. By mid-1948, the Air Force reelevated the Air Proving Ground's status to that of a major command. Early in 1949, Headquarters Air Force requested that the commanders of Air Materiel Command and the Air Proving Ground submit their respective budget estimates for armament facilities at Eglin. Air Materiel Command and the Air Proving Ground could not come to a ready agreement, and in December 1949, Headquarters Air Force established the Air Materiel Armament Test Center at Eglin under Air Materiel Command. More changes soon followed. In January 1951, Headquarters Air Force reassigned the Air Materiel Armament Test Center to the Air

Proving Ground. By this date, the emerging ARDC also expressed a strong interest in sustaining an armament activity at Eglin. While ARDC and the Air Proving Ground continued to disagree about the appropriate assignment of an armament research, development, testing, and evaluation mission, the Air Proving Ground changed the organizational structure of armament efforts at Eglin from a center to a division.[13] In late 1951, Headquarters Air Force separated the Armament Division from the Air Proving Ground (which formally changed to Air Proving Ground Command in December) and assigned it to ARDC as the Air Force Armament Center (AFAC). Eglin Air Force Base remained under Air Proving Ground Command as an installation. Through Air Proving Ground Command and the AFAC under ARDC, the research, development, testing, and evaluation missions for armament, aircraft, equipment, and materiel, as well as sustained materiel readiness missions, went forward at Eglin as the 1950s unfolded. In 1957, the interwoven nature of the missions at Eglin manifested itself again, when the Air Force combined the AFAC with Air Proving Ground Command as a single entity, the Air Proving Ground Center. The former AFAC became the Armament Division under the Air Proving Ground Center, with the center assigned to ARDC within the Air Force power structure at a level equivalent to a numbered Air Force.

Eglin's role at the outset of the 1950s, as the primary armament test site for the Air Force, had evolved from the July 1948 placement of the armament function at the directorate level within Headquarters Air Force. The development of post-World War II armament was of growing complexity and demanded diverse tests for all new equipment. Tests focused not only on whether or not the equipment met military requirements and specifications, but also on whether the equipment was operationally suitable under simulated combat conditions. The Ridenour Committee of the Air Force's Scientific Advisory Board (SAB) had broached the separation of these research, development, testing, and evaluation functions in an analysis of September 1949. The committee had recommended that the first-level testing to meet military needs stay at Eglin, and that the flight testing of armament move to Southern California, to what would become the Air Force Flight Test Center at Edwards (see Volume II, Chapter 3). The physical buildup at Eglin for next-era armament research, development, testing, and evaluation began during Fiscal Year (FY) 1950. As late as December 1951, ARDC wavered on the site choice for its primary armament test center, arguing that the installation might be equally well established at Eglin, Holloman, or Edwards Air Force Bases. The command evaluated multiple factors, including:

- the availability of large open land areas;
- water ranges;
- ground-instrumented ranges;
- rocket launch facilities;
- unrestricted airspace;
- runways;
- types of terrain and particular features;
- year-round flying weather;
- weather conditions for optic testing;
- support and transportation infrastructure;
- power and communications;
- nearby industry;
- location of needed contractors; and,
- fuel storage.

While Holloman ranked first in the 1951 study, ARDC concluded a move from Eglin would lose valuable time and interrupt efforts already in progress. The command assigned the initial

administrative personnel for Eglin's armament center from units dispersed at other Air Force and Army installations. The formative units for the test center were:

- the First Armament Squadron (Chemical), already at the Air Proving Ground;
- the 3208th Chemical and Ordnance Test Group, a combined unit derived from the Army's Aberdeen Proving Ground and Edgewood Arsenal in Maryland, and, from a Strato-Bombing Squadron at Muroc (Edwards) in Southern California; and,
- the 3150th Engineering Test Squadron transferred from Robins Air Force Base in Georgia.

In April, the Muroc unit fell out of the group (just as the Air Force assigned that from Robins to Eglin). The Air Materiel Armament Test Center had a strength of 46 officers, 403 airmen, and seven civilians by late spring, with about $1,000,000 committed to begin construction of the instrumentation facilities. Congress appropriated another $6,900,000 in FY 1951 for physical infrastructure.

Initiation of the Korean War in June also emphasized the necessity for immediate buildup of armament test facilities. Headquarters Air Force requested the Kellex Corporation (which would become the Vitro Corporation by late 1951) to prepare a *Study of Instrumentation of Facilities for the Air Materiel Armament Test Center.* Kellex recommended that the Cold War armament center at Eglin include:

- an armament hangar;
- an addition to the climatic hangar;
- a centrifuge;
- a rocket range with landing strip;
- a sled track;
- a covered firing range and recording laboratory;
- "splatter shields;"
- theodolites;
- "a redesigned Texas type tester;"
- electronics, mechanical, science, optical and photographic laboratories;
- a machine shop;
- an ammunition storage and handling area;
- support buildings; and,
- "computing machines."

The package totaled $42,100,000, more than four times the Air Force estimate of only the year before. Kellex completed their formal study in late December 1950. The same 1951 analysis that had considered a move for the Armament Center from Eglin to either Holloman or Edwards, also reestimated costs: to $84,018,000. In two years, 1949 to 1951, anticipated financing had jumped by a factor of 8.5 (or, by about 850%). Kellex based its engineering report on 42 field inspections and conferences with representatives of the Air Force, Navy, Army, and private industry, as well as with managers of selected civilian and military airfields. The efforts began with meetings at Wright-Patterson and inspections of the armament hangar, Texas Tester, and other armament test facilities on the Ohio base.

Kellex's *Study of Instrumentation and Facilities for the Air Materiel Command Armament Test Center* of 1950 proposed major buildings and the layout of new armament ranges. A key addition suggested at Eglin's main base was a state-of-the-art armament hangar and laboratory (Building 130) (Plate 48). Kellex subcontracted the project to L.P. Kooken in Baltimore, a firm that would handle another major Air Materiel Command effort in 1952: its Special Air Materiel Command (AMC)

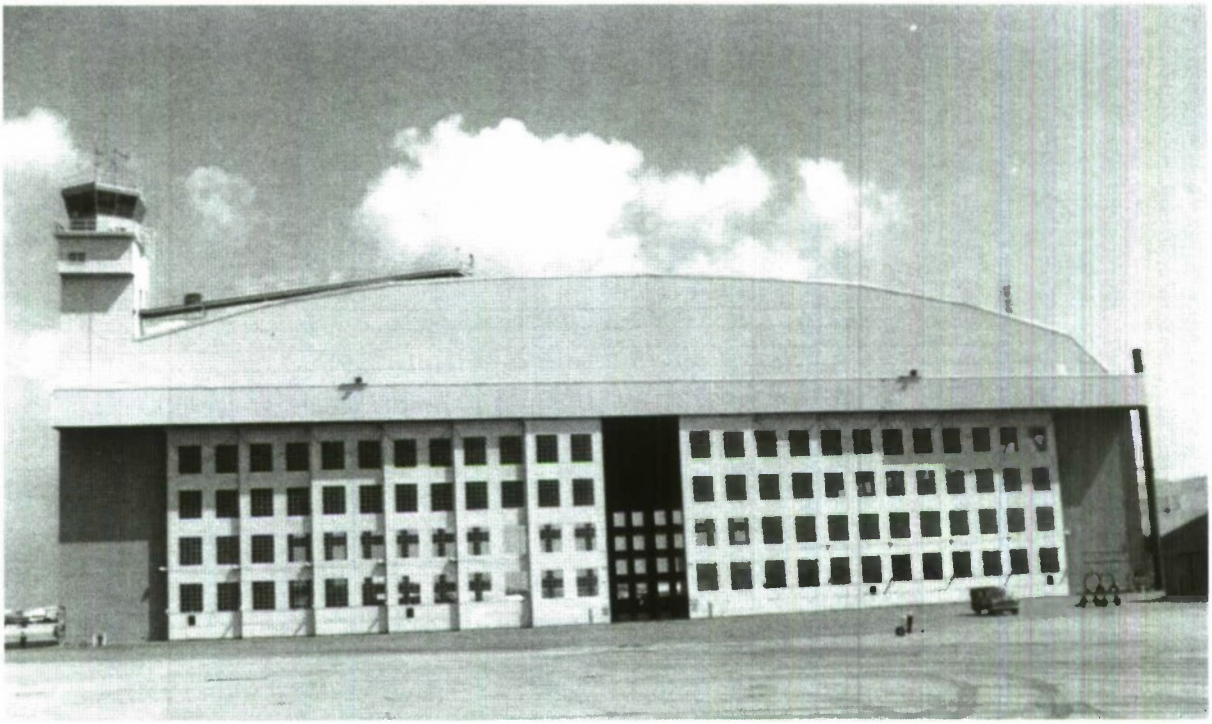

Plate 48: L.P. Kooken. Armament Hangar (Building 130), Eglin Air Force Base, 1951. Photograph of February 2000. C. Dolan for EDAW, Inc.

Warehouse (see Volume I, Part II). Kellex handled its recommendations for armament test ranges at Eglin as two lengthy sections in its report. The firm addressed overall range layouts and instrumentation needs, as well as individual range structures. Eight new range designations, with land areas partially derived from the existing numbered ranges of World War II, were alpha-named:

- Range A, a precision bombing range;
- Range B, a bombing impact range;
- Range C, a bombing salvo range;
- Range D, an air-to-ground rocket range;
- Range E, a free-flight rocket ballistics range;
- Range F, an air-to-ground gunnery range;
- Range G, a moving target range; and,
- Range H, an air-to-air range.

At the time of the Kellex *Study*, the Air Force assumed Range B to be a continuance of Range 51, although Range B would be located over a very large area to the northwest of the main cantonment. The other Kellex ranges all involved substantially new configurations. Range A overlaps the later Range B-70, while Ranges D and G were partially configured similar to the later Range B-71. Range G was adjacent to Range D, with these two ranges functioning as a pair. Range G provided the targets for tests run from Range D. Kellex's proposal for Range G included a two-mile long, standard-gauge railroad track "over which a motor-driven car carrying a target can attain speeds up to about 75 miles per hour." The firm's engineers envisioned multiple ground reference markers lining both sides of the center mile of the track to help guide in aircraft for their passes at the target. Range C is substantially the same as the later Range B-75.[14] Kellex engineers overlaid Range E at Field 1 and the World War II Ranges 56 and 65. The later Ranges C-72 and C-74 have largely absorbed

Range E. Range F was a "range" only in its use designation. To accommodate air-to-ground tests, pilots were to simulate releasing their weapons using the Range D and G pair. The simulations would test fire control systems. For "hot" firing, Kellex construed Range F to be anywhere on Eglin's range lands. The final range, H, was also only for reference purposes. Air-to-air gunnery and rocket tests could occur over any suitable Gulf of Mexico waters. Thus, in effect, the Cold War ranges planned by Kellex were those of A, B, C, D / G, and E—with F and H actually varying on a per mission basis across existing inland and overwater ranges. In the designations of Eglin test areas in 2003, the Kellex additions at the outset of the 1950s are concentrated on Ranges B-70, B-71, B-75, C-72, C-74, and D-51 (see Plate 44). The Kellex ranges of 1950-1951 featured 58 new buildings and structures, as well as numerous theodolites, camera stands, test pads, reference markers, and radars. Several mission-specific test tracks and launch ramps completed the infrastructure.[15]

The 1950s Cold War test ranges at Eglin, then, overlaid the ranges of the early-to-middle 1940s. In order to accomplish the research, development, test and evaluation required for the weapons systems of the next era, the base added infrastructure adjacent to—and interspersed among—preexisting test structures. Eglin personnel also adapted and modified past targets and test infrastructure as their needs changed. The pattern continued up to the present as the armament center developed yet more test sites. Kellex's Range E (Range C-72) is good example of the complexity. Range E sliced through the earlier Range 65, with both the submarine pen and the large target wall of the middle 1940s remaining on site. Kellex had originally planned Range E for three possible locations, including one launching over water from Santa Rosa Island. The final site choice was at yet a fourth location near Field 1. Personnel were to use Range E to test aircraft rockets from the ground, with their performance precision measured to determine rocket ballistics. For Range E, Kellex recommended adapting the instrumentation system in use by the Ballistic Research Laboratory at the Army's Aberdeen Proving Ground in Maryland. Kellex planned instrumentation for Range E as 16 camera stations, control station (Building 9500), three launch pads, preacceleration launch ramp (Building 9503), two blockhouses (Buildings 9504 and 9505), observer's gallery (Building 9511), rocket assembly building (Building 9521), temperature conditioning building (likely Building 9512), three small ammunition magazines (Buildings 9518, 9519, and 9520), and 27 reference markers. The three launch pads included one directly behind the preacceleration ramp, one for the installation of temporary launchers of various types, and one intended for aircraft brought to the range. Kellex proposed that the latter ramp be 160 feet in diameter, to allow turning of the largest possible aircraft required for test. As built, Range E also included three smaller windowless personnel bunkers (called "barricades") along the ramp's launch path (Buildings 9506, 9507, and 9508). Following testing at Range E from the early 1950s, Eglin added another test track complex with a similar complement of support structures on today's Range C-74 at mid-decade. More changes continued as the decades unfolded. Integrated into Range C-72 at the former Range 56, AFSC built a prototype protective shelter for fighter aircraft in 1963. The Air Force Special Weapons Laboratory at Kirtland Air Force Base in New Mexico conducted tests at the site (see Volume II, Chapter 8). As of 1967, base civil engineering designed and built a "fortified defensive array"—an interconnected series of underground tunnels, open trenches, and foxholes, loosely evocative of a system of Vietnamese fortifications—for the Directorate of Technical Applications for Southeast Asia activated at Eglin. Multiple other targets and test infrastructure existed on Ranges C-72 and C-74 by the close of the Cold War[16] (Plate 49).

In addition to armament testing during the 1950s and early 1960s, Eglin supported a large variety of Air Force tenant and specialty missions. Immediately after World War II, the 1st Experimental Guided Missiles Group tackled not only the JB-2 mission, but also that of developing pilotless drones to conduct atmospheric sampling during atomic tests at the Pacific (Atomic) Proving Ground in the Marshall Islands and at what later would be named the Nevada Test Site (operated by the Department of Energy). The drone project began in 1946 and became the principal guided missiles mission at Eglin from 1950 into 1954 (see Volume I, Part III).[17] As of 1956, Eglin received another missile assignment—to develop a suitability testing site for Bomarc, the ADC surface-to-air interceptor

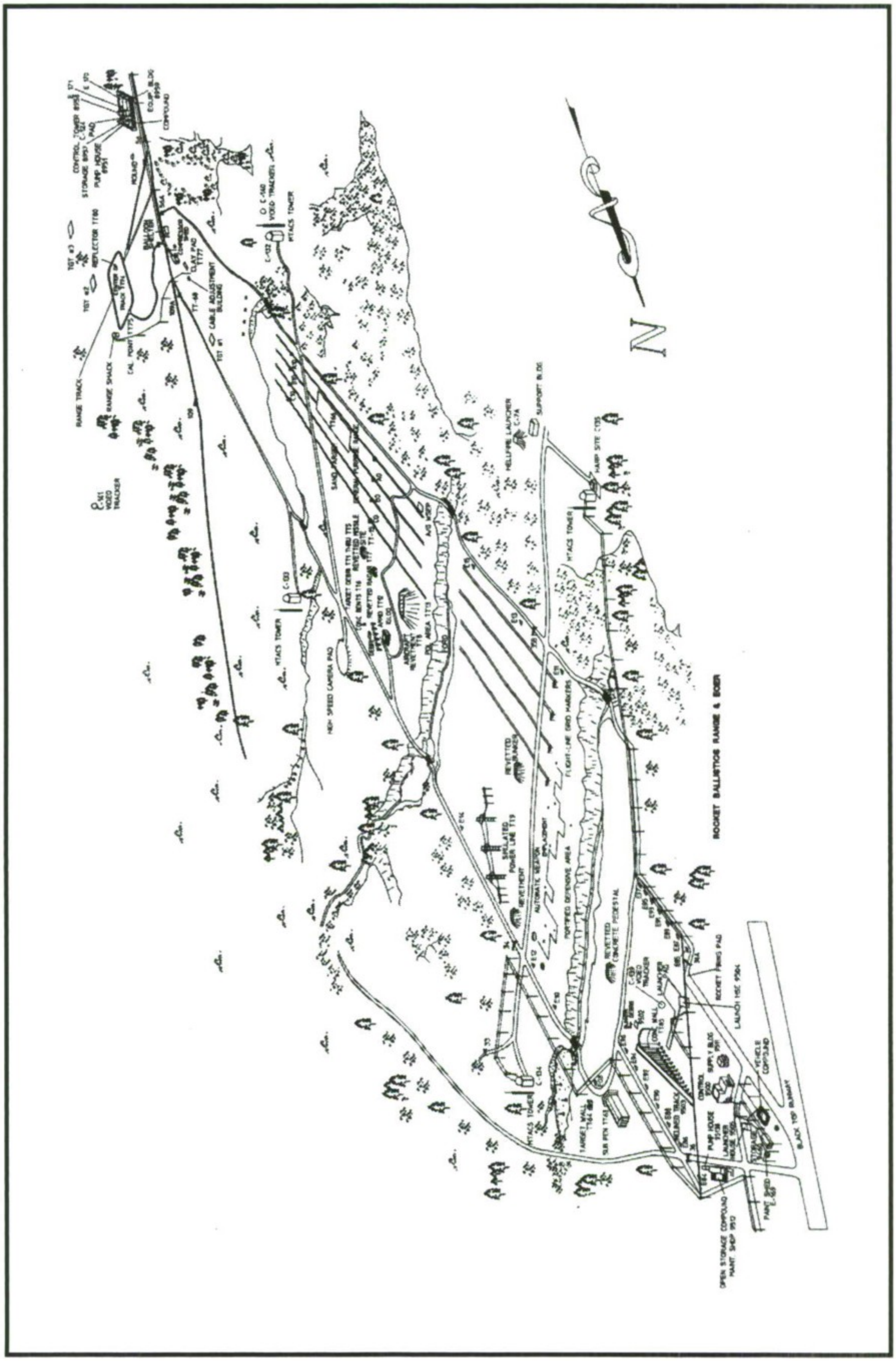

Plate 49: Range C-72, Eglin Air Force Base. Perspective drawing of target and test compounds. In *Land Test Areas*, volume II of *AFDTC Technical Facilities*, July 1996.

missile coupled with the Semi-Automatic Ground Environment (SAGE) air defense command-and-control program (see Volume I, Part IV). Bomarc was a joint project of Boeing Aircraft and the University of Michigan Aeronautical Research Center. The Bomarc test complex on Santa Rosa Island was under construction as of 1957. Between 1957 and 1960, the Air Force erected a series of launchers and a blockhouse on site, with the launch facilities delineated as Types I-V (with some versions built only once and others in multiples). J. Gordon Turnbull, the architect for the Air Materiel Command's underground plant project (see Volume I, Part III), designed the Type I launcher, the blockhouse, and most of the other individual buildings supporting the test complex (Plate 50). He was subcontracted to Burns & Roe, the architects for the SAGE Combat and Direction Centers. As of 1967, the Bomarc blockhouse (Building 12250) managed not only the continuing Bomarc operations, but also the vertical probe launch stands on Santa Rosa Island. Today, the Bomarc launchers are no longer extant. Bomarc operational testing at Eglin necessitated an expansion of its overwater range, as well as increased instrumentation.

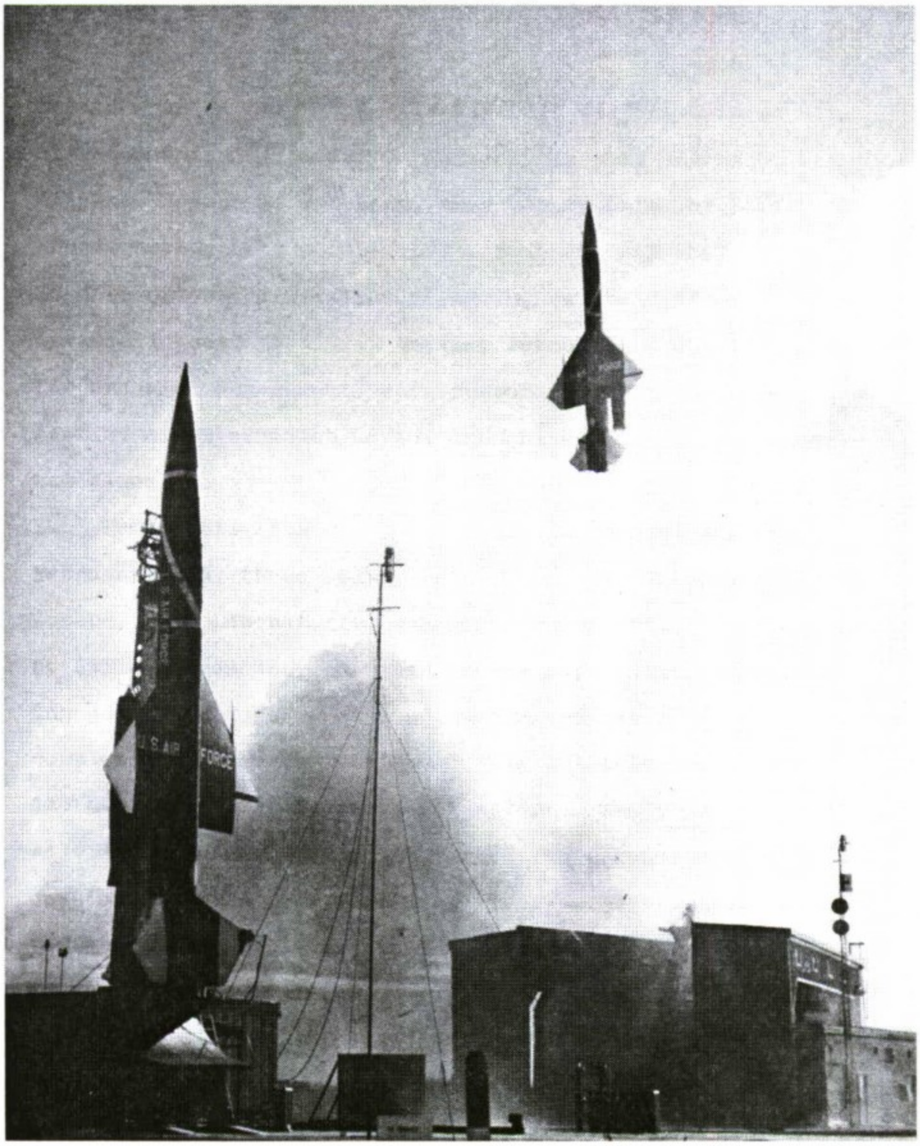

Plate 50: Bomarc Launch, Site A-15, Santa Rosa Island, Eglin Air Force Base, undated. (No longer extant.) In *An Overview of ADC Weapons 1946-1972.*

Beginning in FY 1957, the Air Force moved toward the EGTR, a range expanded to accommodate the 450-mile trajectory of the Bomarc B by its completion in 1961. Instrumentation employed for overwater tests featured eight tracking radars and seven theodolites on Santa Rosa Island, a telemetry ground station, and additional mobile equipment as of early 1957. Two control centers, the Range Control Center (A-20) (Building 12722) located west of Field 9 (Hurlburt Field), and the Drone Control Center (A-3) (Building 8320) located on the eastern end of Santa Rosa Island, were the key guidance facilities. Site A-20 could also track space objects, a very important capability after the Soviet launching of Sputnik in October 1957 (see Volume I, Plate 123). Site A-20 became operational in November 1957 as the Satellite Tracking Facility. Bomarc also required major off-site instrumentation, including Sites D-3 at Cape San Blas, D-4 at Anclote Point, D-5A at MacDill Air Force Base, D-7 at Marco, and D-8 near Key West. The 4751st Air Defense Missile Squadron (Bomarc) launched 140 Bomarc missiles from the Santa Rosa Operational Suitability Test site between 1958 and 1962, training 1,350 men for the 10 final Bomarc tactical sites in the United States and Canada. As of 1961, the 4751st also supported annual retraining for the Bomarc squadrons on alert. After ADC retired the Bomarc A in 1964, the Bomarc installations shipped the missiles to Eglin, where the Air Force modified them for use as high-altitude, supersonic target drones (the CQM-10A program). In 1972, the Air Force converted the Bomarc B to a target drone, following full stand down of the missile. F (fighter) -4s, F-106s, F-15s, and F-16s all practiced firing their air-to-air weapons against Bomarc drones over the EGTR. The Air Force launched the final Bomarc drone at the Santa Rosa test site in late August 1985.[18] Eglin personnel also erected a mobile launcher at Site A-10 for a similar mission using the Mace guided missile. The Mace, a winged, ground-to-air missile of unmanned-aircraft type, had evolved from the Matador of the late 1940s. The Mace, like Bomarc and Nike (see below), served as a target drone at Eglin during the late 1960s. Eglin adapted the support buildings for the 1st Experimental Guided Missiles Group (initially for the JB-2) at Site A-10 for Mace.

Another very important site at the base was A-19, a cluster of facilities that had multiple lives over the decades of the Cold War. Eglin originally configured Site A-19 as the Air Force Operational Test Center (AFOTC) at the outset of the 1950s. By the early 1960s, the location functioned as the Radar Control Center and Mission Control. The Air Force developed Site A-19 as a pair of primary buildings: Type 2 and Type 4 Operations Buildings planned and engineered for nationwide construction (see Volume I, Part III), and always erected with an independent power station and operational radars. ADC typically built these structures at installations that hosted command posts for the Aircraft Control & Warning (AC&W) air defense network of the 1950s (see Volume I, Part IV). Eglin's Site A-19, however, adapted the Type 2 and Type 4 Operations Buildings for a unique use. The pair (Buildings 954 an 955) is an excellent example of the complexity of intertwined Air Force missions, spread across multiple commands. The Chicago architectural-engineering firm of Holabird, Root & Burgee had designed the programmatic Type 2 and Type 4 Operations Buildings in 1948-1949 for Headquarters Air Materiel Command at Wright-Patterson. Air Materiel Command in turn handled oversight of the buildings' design for ADC, who had mission responsibility. ADC operated 16 Air Defense Control Centers (ADCCs) [Type 4 Operations Buildings] and 85 Air Defense Direction Centers (ADDCs) [Type 2 Operations Buildings] as the American command post network in the years before SAGE came on line. ARDC also participated. Its Rome Air Development Center (RADC) at Griffiss Air Force Base in New York and Cambridge Research Laboratories / Center at Hanscom Air Force Base in Massachusetts improved the radars and electronics communications equipment required for the command posts (see Volume II, Chapters 5 and 12). And yet at Eglin, Air Proving Ground Command sponsored the AFOTC at Site A-19—not the commands that developed, improved, and used the specialized structures across the United States. The Type 2 (Building 954) and Type 4 (Building 955) structures were under construction at the base in late 1952. The first mission of the pair at Eglin was operational suitability tests (OSTs) of fighter aircraft and radar systems, as configured within the AC&W network under ADC. A preexisting Air

Operations Center (AOC) was in place at Site A-19 in a Jamesway hutment (Building 950) to orchestrate OSTs in progress while construction was underway for Buildings 954 and 955. Project Quick Fix took place in the temporary setup in Building 950 in very early 1953 through the Cambridge Research Center at Hanscom Air Force Base in Massachusetts. Quick Fix addressed modifications of the ADCC and ADDC network.[19] (An existing scramble hut, Building 123, served as the fighter alert crew quarters for the air defense OSTs at Site A-19. The 1949 hut was entirely underground, at the end of the flightline.[20])

Personnel at Site A-19 tested not only new American equipment as it became available, but also a captured Soviet MiG (Mikoyan-Gurevich) -15 and Wurzburg radar in the middle 1950s—in scenarios that matched American equipment against its enemy counterparts. Air Proving Ground Command occupied the Type 2 and Type 4 Operations Buildings at Eglin from July 1953 to February 1958, nearly coincident with its host role at the base. (ARDC became the host command at the installation in December 1957.) The AFOTC took over existing OST responsibilities from the 3200nd Test Wing. The center included a Mission Control Branch (who would use the Type 4 Operations Building), five divisions, and one detachment. The Air Defense Division featured Interceptor, AC&W, and Special Projects Branches. The other four divisions were Tactical Air, Strategic Air, Electronics, and Support Services. AFOTC Detachment #1 operated off site, at Kirtland Air Force Base in New Mexico, and was responsible for integrated OSTs involving atomic weapons (see Volume II, Chapter 8). In 1955, planned projects of the AFOTC featured OSTs for the F-89D, F-86D, and F-86K fighter aircraft; automatic and manual identification systems; and, the AN/FPS-6 radar. Completed projects included the "F-86D versus MiG-15" and "Employment of Multiple Interceptors Against Multiple Bombers," among numerous others. The multiple interceptor-bomber test was also known as Project Wolf-Pack. The Interceptor Branch of the AFOTC supervised the test, setting it up in "a typical ADC environment in Southern California." Major off-site exercises such as this one allowed the OSTs at Eglin to gather additional information.[21] As of 1958, Site A-19 continued its radar test mission under ARDC. In 1961, Site A-19 still included AN/FPS-6 and AN/FPS-20 air defense surveillance radars.[22] The AN/FPS-6 dated to the early 1950s and the AN/FPS-20 to 1956 forward. By this date, the Type 2 Operations Building at Site A-19 (Building 954) had become the Radar Control Center for Eglin (Plate 51), with the Type 4 Operations Building at the location (Building 955) continuing as Mission Control.

Many sites associated with Eglin and the EGTR supported radar testing by the RADC at Griffiss, similar to the OSTs for radars at Site A-19. The RADC was the radar and electronics R&D center for ARDC (see Volume II, Chapter 12). Between mid-1948 and the end of 1957 however, these radars operated under the jurisdiction of the Air Proving Ground Command, not ARDC. After Headquarters Air Force integrated the Air Proving Ground with the Armament Test Center under ARDC, radar OSTs at Eglin occurred through the Air Proving Ground Center. As of December 1957, the Air Proving Ground Center and its follow-on the Armament Development and Test Center (1968 forward) were operational units under ARDC / AFSC. Examples of major OSTs for Air Force radars on Eglin's ranges and off site at individual locations in Florida and Alabama are numerous. The radar and electronics test locations hosted combinations of radars, ultra-high frequency (UHF) and very-high frequency (VHF) transmitters, receivers, tracking telescopes, theodolites, and, frequency monitoring and interference control instruments (Plate 52). After ARDC / AFSC finished up OSTs for individual pieces of equipment at Eglin, these items typically remained operational for the base and EGTR. In most cases, Eglin reconfigured the radar and electronics equipment to create other test environments for the base. In 1961, the AN/FPS-6 and AN/FPS-20 at Site A-19, for example, were a part of an electromagnetic countermeasures test environment on base that also incorporated four AN/FPS-16s at Site A-20. The AN/FPS-16 was another major detection and tracking radar developed by the RADC. The AN/FPS-16 provided "accurate space-position data for evaluating the performance of airborne objects...[and was]...capable of acquiring and accurately tracking

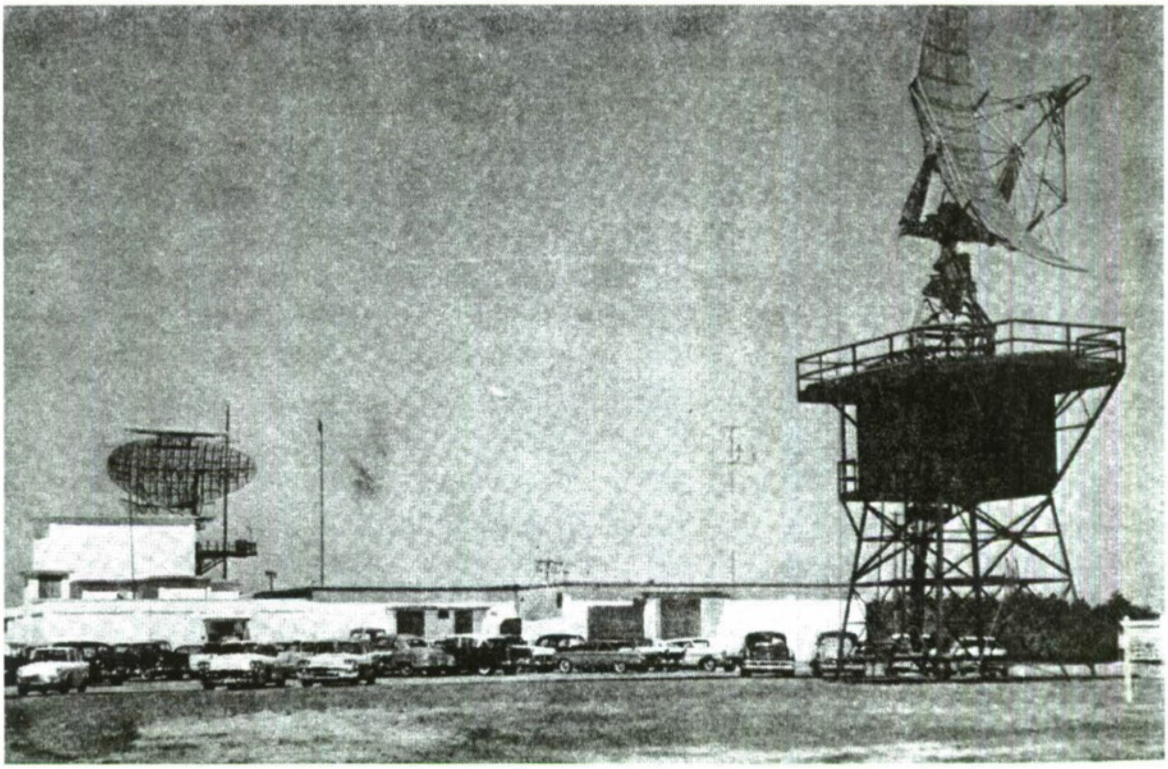

Plate 51: Holabird, Root & Burgee. Radar Control Center (Building 954), Site A-19, Eglin Air Force Base. Designed as a Type 2 Operations Building and erected for the Air Force Operational Test Center in 1952-1953. In *History of the Air Proving Ground Center 1 July – 31 December 1961*, volume 4.

missiles...rockets, aircraft, nose cones, boosters, tankage assemblies, instrument packages, and debris." The Air Force configured those at Eglin of the early 1960s to track to distances of either 200 or 500 nautical miles. The Air Proving Ground Center's electromagnetic test environment of 1961 also sustained three AN/FPS-16 radars at each of its Cape San Blas, Anclote Point, and Marco test sites along the west coast of Florida. Twelve of the total 13 AN/FPS-16s were also incorporated into the surveillance radar subsystem for Eglin and its test ranges.[23]

Two other examples of RADC radars in operational test at Eglin during this period were the AN/FPS-30 and the AN/FPS-85—both extremely important radars for the future development of long-range tracking of intercontinental ballistic missiles (ICBMs). The RADC supervised the OST for the AN/FPS-30 at Site C-1 on the southernmost tip of Range 52 during 1959-1961 (see Plate 52), and sequentially established that for the AN/FPS-85 at Site C-6 to the east of the same range (see Plate 44). The AN/FPS-30 was the radar engineered for east and west extensions of the Distant Early Warning (DEW) Line erected across Alaska and Canada between 1953 and 1957. The east extension ran across Greenland from Cape Dyer, Baffin Island to Keflavik Air Base in Iceland. Planning and management of the DEW Line Extension was the joint responsibility the RADC and the Electronic Systems Center at Hanscom (see Volume I, Part II). Underway in 1956, the program came to be known as DEW East. In early 1959, DEW East included plans for a domestic test site at Eglin. Five DEW East radar stations stretched across Greenland to Keflavik. Two of the stations in central Greenland were icecap sites and presented unique problems focused on interference between communication systems and the new high-power radar. The Site C-1 test facility at Eglin was engineered as a "simulated icecap site" (Plate 53). In addition to running OSTs for DEW East, the

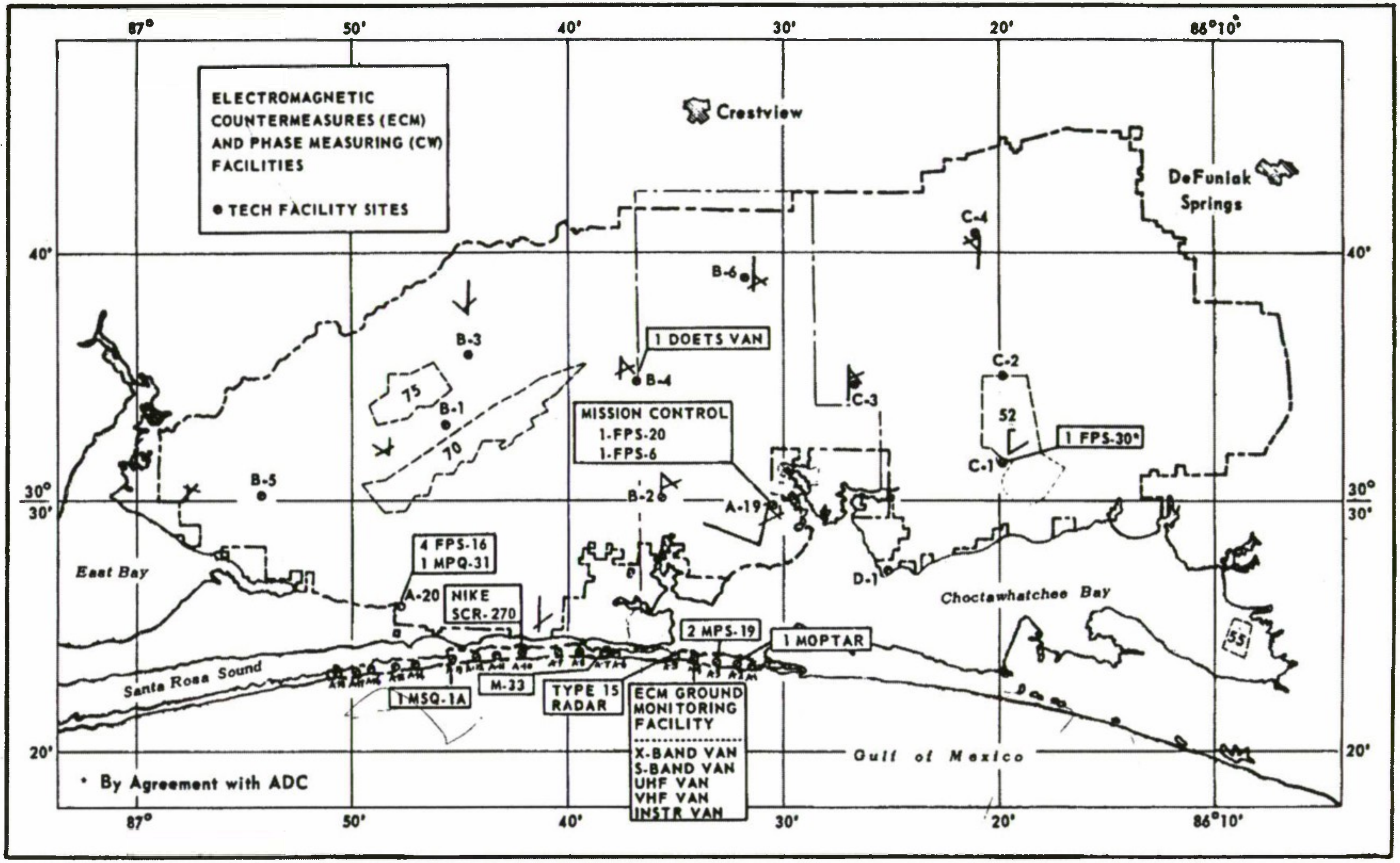

Plate 52: Radars and Tracking Devices (Electromagnetic Countermeasures and Phase Measuring Facilities), Eglin Air Force Base, 1961. In *History of the Air Proving Gronnd Center 1 July – 31 December 1961*, volume 4.

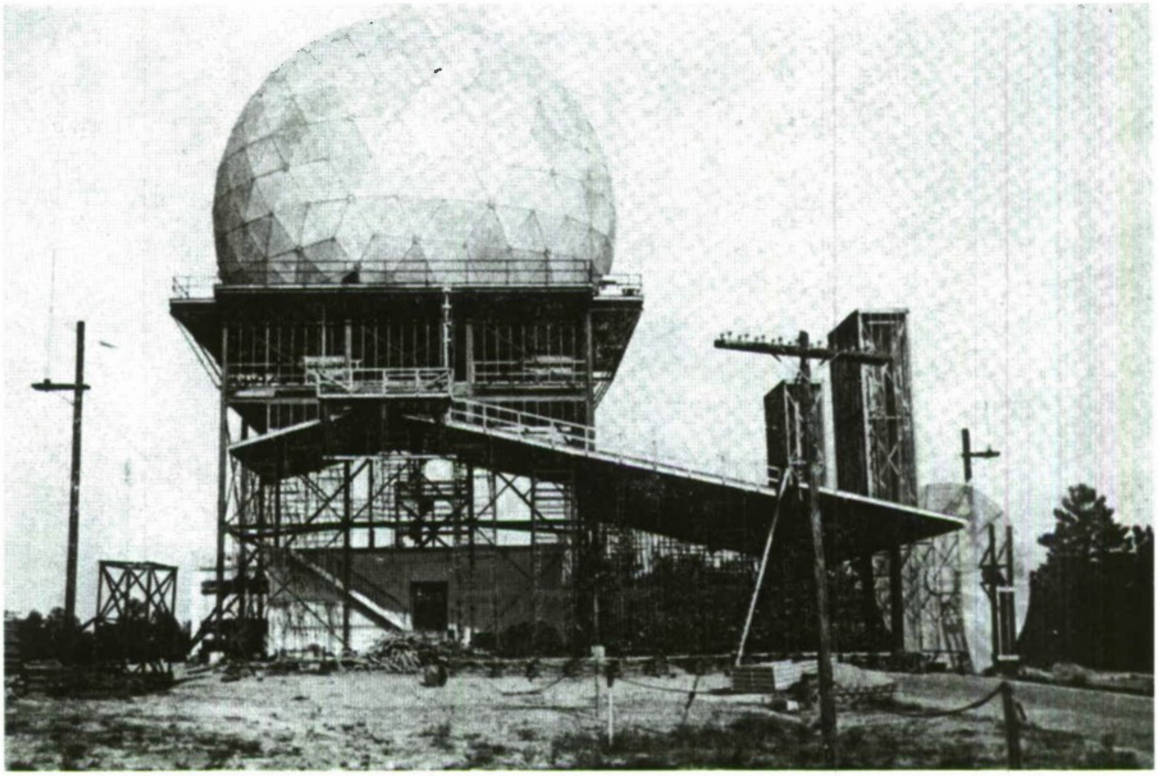

Plate 53: Bendix. AN/FPS-30 Radar at the Simulated Icecap Test Area for the Eastern Extension of the Distant Early Warning (DEW) Line, Site C-1, Eglin Air Force Base, 1959-1961. In *DEW East Completion Report*, 30 March 1962.

Air Proving Ground Center also used the AN/FPS-30 radar at Site C-1 as a training facility for ADC. The DEW East radars were operational as of October 1961.[24] The second example of an RADC radar in test at Eglin in the 1960s was the AN/FPS-85 at Site C-6. The AN/FPS-85 was the first large phased-array radar built by the American military, and paralleled efforts by the United States Army at this same time. The AN/FPS-85 was under construction at Eglin during 1962-1969. Thereafter, ADC and Space Command / AFSPC operated the facility for tracking sea-launched ballistic missiles (SLBMs) and satellites (space objects). The AN/FPS-85 (Building 8640) continues to operate in 2001, and is one of 10 operational large phased-array radars built by the Air Force and Army between 1962 and 2001[25] (see Volume I, Part IV and Volume I, Plate 116). Both the AN/FPS-30 and AN/FPS-85 were radars developed for the Air Force by Bendix.

Other specialized and tenant missions at Eglin during the 1950s into the 1970s included those of high-altitude and vertical probe testing, with launch facilities also on Santa Rosa Island at Site A-11 (with support at the former 1st Experimental Guided Missiles Group at Site A-10); testing and evaluation for the nuclear-tipped Hound Dog air-to-air missile (the Guided Air Missile [GAM]-77) and its paired decoy missile the Quail (GAM-72); assignments from ARDC / AFSC for biological and chemical weapons development; and, SAC and TAC alert.[26] (see Volume I, Parts III and IV and Volume I, Plates 98-100 and 119-123). (Volume I addresses these missions in detail.) The Cambridge Research Laboratories / Center at Hanscom was heavily involved in the high-altitude and vertical probe tests, while Wright-Patterson directed much of the effort toward biological and chemical weapons tests at Eglin. Again, the interconnected sites erected on Eglin's ranges to support Category I-IV tests and OSTs for ARDC / AFSC and Air Force, Army, and Navy tenant organizations were numerous and are not addressed here in detail. One example of the inherent layered complexity of military tests run at

Eglin is the Nike ground-to-air interceptor missile. The Nike was an Army interceptor missile developed in competition with the Air Force Bomarc. The missile went through upgraded improvements during its deployment: the Nike-Ajax (deployed during 1954-1958), Nike-Hercules (deployed during 1958 into the late 1960s), and the Nike-Zeus (in R&D as of 1956, with initial testing in 1962). The final iteration of the Nike was a high-altitude antimissile missile, a guided missile engineered to intercept ICBMs. Researched Nike facilities at Eglin included three distinct types and locations:

- As of November 1955, Air Proving Ground Command had designs underway for "Inland Nike Site Facilities" (Building 4965) at the western edge of today's Range B-71. The site included three tracking antenna pads on steep, man-made hills; a maintenance and modification structure with an interior pit; and, a paved area lined by cable trenches for seven parked instrumentation vans. The date of construction for these facilities, also known as Site G-17, suggests that testing was for the Nike-Ajax.[27] The program was Army, without overlap for the Air Force.

- By at least 1959, the Air Proving Ground Center conducted Nike-Hercules demonstration launches at high-speed target drones.[28] As of mid-1967, Eglin had two Nike launchers at Site A-13A on Santa Rosa Island, one for the Nike-Hercules and one for the Nike-Ajax. The presence of a Nike-Ajax launcher suggests that Nike demonstration launches may have predated those for Nike-Hercules, with Nike activities at Site A-13A from about 1958 forward. In 1958-1959 also, the Air Proving Ground Center added an associated radar at Site A-13. The radar supported both Nike and Bomarc launches from Santa Rosa Island.[29] This Nike mission was one that combined Army and Air Force interests.

- At the outset of the 1960s, the Air Proving Ground Center used the Nike in combination with other vehicles for high-altitude probe tests. Air Force personnel used multistage and boom-launchers at Sites A-11 and A-15A on Santa Rosa Island to fire probes comprised of surplus military rockets retired from service (such as the earliest Nikes) and the test packages. Examples launched at Site A-11 included the Nike-Asp, the Nike-Cajun, the Nike-Cree, and the Exos. The latter probe had three stages: a first-stage Honest John rocket, a second-stage Nike missile, and a third-stage Yardbird developed by NASA. The third Nike mission at Eglin was an Air Force and NASA endeavor.[30]

In another occurrence after 1960, TAC substantially enlarged its presence at Eglin. TAC would sustain its growth and role at the installation throughout the remainder of the Cold War. TAC's Electronic Warfare Test Center of the early 1950s at Field 2 evolved into the Air Force Special Warfare Center at Field 9 (Hurlburt Field) as of mid-decade. The Air Force Special Warfare Center continued as a major Air Force presence at Field 9 into 1974. A related organization also emerged as of 1963, the Tactical Air Warfare Center (see below). During the buildup for Vietnam, host and tenant personnel percentages shifted dramatically at Eglin. In mid-1957, the Air Proving Ground Command had sustained over 11,000 personnel on base with a tenant strength of just under 4,800. By 1972, the Armament Development and Test Center under AFSC had about 44 percent of the total personnel at Eglin, while tenant missions had climbed to nearly 56 percent. Overall personnel increased from about 15,800 to 17,850. Tenant organization buildup began in 1963 and was directly tied to the limited-war effort in Southeast Asia. Related missions also involved the integration of friendly foreign nationals in training activities at Eglin "to sustain their resistance to the Communist threat." In 1972, nearly 73 percent of the tenant missions at Eglin were those of TAC. The command sustained a major presence not only on the main base, but also at Fields 2, 3 and 9. At the height of the Vietnam War, 7,233 of the 9,957 men and women on base who served tenant organizations reported to TAC.[31]

On 14 April 1961, TAC created the 4400th Combat Crew Training Squadron at Eglin, nicknaming the unit Jungle Jim. The squadron, commanded by Colonel Benjamin H. King, trained South Vietnamese air forces in counterinsurgency and conducted varied air operations. Aircraft of the 4400th were transports (16 C [cargo] -47s), light bombers (eight B-26s), and fighter-bombers (eight Navy T [trainer] -28s)—all propeller aircraft. The B-26 dated to World War II, while the C-47 was a pre-World War II aircraft. By early 1962, internal Air Force documents for TAC's Special Air Warfare Center included the mission of the 4400th Combat Crew Training Squadron. TAC heavily modified aircraft for the squadron, focusing on armor for the T-28 and a doubled fuel capacity, stronger landing gear, and jet-assisted takeoff (JATO) racks for the C-47. The altered T-28 could carry 1,500 pounds of bombs and rockets. Command personnel also fitted the plane with two 50-caliber machine guns. As of late August 1961, Jungle Jim was still an elite unit in training. The Air Force had covertly established the squadron within TAC at Eglin under the guidance of Air Force Chief of Staff General LeMay. In November 1961, Detachment 2A, 4400th Combat Crew Training Squadron, arrived at Bien Hoa Air Base about 10 miles outside Saigon. Detachment 2A included 155 men on temporary duty from Eglin. Four modified C-47s (redesignated SC [search / cargo]-47s: for search-and-rescue missions), eight T-28s, and four RB (reconnaissance bomber) -26s equipped the detachment. The code name for the Vietnam detachment of Jungle Jim was Farm Gate. (Detachment 1 of the squadron trained as paratroopers in Mali, West Africa.) Other Air Force detachments began to deploy to Southeast Asia, in the true beginnings of an expanded and sustained United States Air Force presence. The Jungle Jim / Farm Gate operation from Eglin was among the very first of the war.[32]

During 1961, the United States Army also sought strengthened close air support and tactical airlift directly from General LeMay—focused on the unfolding American military needs in Southeast Asia. The Army request evolved into the Air Force Tactical Air Warfare Center in November 1963. The Tactical Air Warfare Center immediately initiated planning for joint Army and Air Force tests and evaluations to enhance the tactical air support of ground forces. As of 1964, the Tactical Air Warfare Center augmented Army efforts during its Indian River and Goldfire exercises. The center also took the first collaborative steps toward deficiencies in equipment, tactics, and training. Emphasis shifted to using off-the-shelf items and to an improvement of TAC's capabilities in this new role. In 1965, the Tactical Air Warfare Center turned to the development of surface-to-air missile (SAM) countermeasures in response to North Vietnam's introduction of SAMs into the conflict in Southeast Asia. At this point in time, the United States Air Force had virtually no defense against SAMs. The Tactical Air Warfare Center developed and tested the F-4G (Wild Weasel) as a modified fighter aircraft more capable of flying in an environment with SAMs. The center simultaneously tested radar homing and warning devices, and aircraft electronic countermeasures jamming pods. The Tactical Air Warfare Center next developed the F-5, an inexpensive, simple fighter intended to be "beneficial in lower levels of conflict, such as in Southeast Asia." As the war continued in Vietnam, the Tactical Air Warfare Center developed "night operations, improved tactical communications, and weapons systems designed to interdict enemy supply lines and troop movements." As of 1971, the center became the "Air Force focal point for tactical airlift, reconnaissance, and special operations." The Tactical Air Warfare Center added air-to-air weapons evaluation to its mission the next year.[33]

To augment TAC training for the Vietnam War, Eglin sustained a variety of infrastructure on its ranges supporting jungle warfare. While some of the targets and test features were quite ephemeral, others were complex and covered large acreages. The fortified defensive array of 1967 on Range C-72 included 340 linear feet of interwoven underground tunnels, with two main vertical entry shafts (see Plate 49). The Vietnamese tunnel complex did not directly imitate the Viet Cong system, yet it did serve as an aerial and ground target for bombing and troop training. Project Underbrush was a much more comprehensive jungle warfare effort at Eglin of this same period. Formal planning for Underbrush had begun through AFSC in December 1965. Project Underbrush included both static

and dynamic targets such as huts, shelters, weapons, tents, vehicles, trucks, bunkers, mannequins, and live troops. The Air Force set up Underbrush specifically for the Vietnam War, although the area continues as a major, highly secured test complex in 2003. Project Underbrush covered 64 square miles on the eastern Eglin ranges to the southeast of the AN/FPS-85 location (Site C-6). The Columbus Division of North American Rockwell developed the Underbrush test facilities for the Reconnaissance Exploitation Section, Intelligence and Reconnaissance Division, of the RADC. The Rome laboratories at Griffiss established the Project Underbrush area to "evaluate the operational capability of reconnaissance sensor systems in a simulated Southeast Asian (SEA) environment," noting that Underbrush also offered a comparable test environment for Panama, Puerto Rico, and Hawaii. The RADC maintained the database of Underbrush test results.

Project Underbrush included four village sites set up with varying degrees of foliage cover, extensive underground tunnels, sampan slips on Alaqua Creek, simulated SAM sites, antiaircraft emplacements, truck and jeep tactical target arrays, simulated rocket sites, and an assault landing strip (Plate 54). The runway featured a bomb-damage assessment portion that was 1,000 feet long by 100 feet wide, with 10 simulated bomb craters. Two segregated test sites were also a part of Underbrush: Ranges B-70 and B-75. B-70, a "rice paddy area," was a very large target range, about 13 miles long and one-and-a-quarter miles wide, east of Field 7. The outlines of B-70 generally overlaid those of Range D from 1950-1951. The paddy supported countermeasure trials against shallow-water mines, mine clearing efforts, line charges, and breaching of beach obstacles. Project Underbrush adapted

Plate 54: Columbus Division of North American Rockwell. Project Underbrush Site IV, South Sampan Dock and 36-Foot Sampan, Eglin Air Force Base, 1970. In *Underbrush Simulated Test Complex Eglin AFB Reconnaissance System Test Planning Guide*, 31 July 1970.

preexisting instrumentation from the early 1950s Range G as a part of its use of the area. Instrumentation included several types of spotting towers that lined both sides of the range and a large blockhouse (Buildings 9300-9318). The blockhouse sat with a second range control station (blockhouse) for Project Bee-Line of ca.1951 (Building 8970).[34] Range B-75 was also a bombing target area for Underbrush, with clustered vehicles, panel targets, radar reflectors, and resolution targets. Multiple military agencies and their contractors conducted tests using the Project Underbrush complex at Eglin. The RADC and Eglin jointly coordinated access and project setup. Two other target and training projects for the Vietnam War included those of a mockup of the Ho Chi Minh Trail and of the Son Tay prison camp. For the Son Tay effort, Air Force Special Operations, active at Eglin from April 1962 to July 1974 under TAC, built a crude full-scale mockup of the prison camp using two-by-fours and target cloth (a fine mesh wire screen). The Special Operations group trained at night and dismantled the camp before daytime overflight of the Soviet satellite Cosmos 355. (Men filled in the post holes and rolled up the wire screen walls of the mockup.) Although the Son Tay raid was a failure in November 1970 due to misinterpretations of American reconnaissance photographs, conditions for prisoners held by the North Vietnamese did improve thereafter—in part due to the press coverage surrounding the entire Son Tay episode.[35]

Hardened aircraft shelters were yet another major program run at Eglin from 1962 until 1991.[36] The very complicated program was initially tied to the war in Vietnam, but also supported the needs of the North Atlantic Treaty Organization (NATO) and American airbases worldwide. By mid-1962, various elements of the Air Staff, including the Directorate of Civil Engineering, began formal studies "relative to protection of fighter-type aircraft on overseas bases." First evaluations discussed "limited hardness" with reference to "incident over-pressure in the lower range," as well as earth-mounded structures resistant to non-nuclear weapons and open revetments. Before the close of the year, the Secretary of Defense backed the development of an earth-mounded shelter that was intended to survive the heavy weaponry of traditional warfare. The prototype shelter, built on Eglin's Range 56 (within the later Range C-72A), was in place as of May 1963 (see Plate 44). Munitions testing continued at the site into 1965. Headquarters Air Force had assigned AFSC the responsibility for engineering the prototype. In response to early programmatic parameters, the command focused particular attention on the shelter's armored doors. Both the Air Force Armament Laboratory at Eglin and the Air Force Weapons Laboratory at Kirtland participated in tests, with the Air Force Weapons Laboratory involved in a much more extensive program for hardened structures (see Volume I, Part III). Eglin tested pairs of redesigned doors in the climatic hangar at –45 and –65 degrees F, and as installed on the Range 56 shelter. Tests at the shelter included air-delivered napalm. The extensive door tests were part of Project 5968W-1 by the Air Force Weapons Laboratory. During the first half of 1966, the protective construction program for aircraft shelters, planned for worldwide deployment, took on the more formal name of the Theater Base Vulnerability (TAB VEE) Study Group. TAB VEE was a field study conducted at Bitburg Air Base, Germany, during 1964 and 1965. TAB VEE concluded that dispersal and aircraft sheltering would provide the highest probability of survival against conventional weapons. The FY 1966 Military Construction Program included $22.4 million for shelter construction. While the TAB VEE program solidified for NATO, AFSC went forward with other types of protective shelter tests on Range 56 at Eglin, including a fighter aircraft revetment, and a revetted radar, fuel storage area, and munitions igloo. At the same time, the conflict in Vietnam escalated to war, with an urgent need for aircraft protection at air bases in South Vietnam. AFSC next initiated a protective aircraft revetment program for Vietnam, with testing and developmental work through the Air Force Weapons Laboratory at Kirtland, and additional physical testing on the UTTR associated with Hill Air Force Base in Utah (see Volume II, Chapters 6 and 8). The Air Force erected about 1,000 protective aircraft revetments at 10 air bases in South Vietnam.

In 1965, the Air Force moved ahead with a more comprehensive aircraft shelter program at Eglin, after completing tests on the prototype structure and beginning construction of aircraft revetments in

Vietnam. From 1966 forward, the program name TAB VEE referenced the development of first-generation hardened shelters for American air bases and those of her allies. (The Air Force used the program name most frequently for NATO hardened aircraft shelters.) Paralleling TAB VEE, the Air Force inaugurated a program refined specifically for Vietnam entitled Concrete Sky. Simultaneously, AFSC initiated Project 1597, "Protective Shelters for Tactical Aircraft," to research, develop, evaluate, and test shelter cover materials. The 560th Civil Engineering Squadron at Eglin directed Concrete Sky, with the Air Force Weapons Laboratory at Kirtland handling Project 1597. The squadron was a TAC unit that was charged with establishing the Civil Engineering Field Activities Center at Eglin. Planning for the center began in November 1966, with instructors and supervisors rotating in from Southeast Asia to Field 2 during early 1967. The 560th Civil Engineering Squadron had previously erected support structures and revetments in Vietnam as a Red Horse (construction) squadron. At Field 2, Concrete Sky was just one of multiple missions focused on infrastructure needed for the war effort. Concrete Sky was a long and complicated project, with 10 phases between late 1966 and the middle 1970s. AFSC set up initial tests at Field 2, including three different prototype shelters in Concrete Sky I and II (Plate 55). Individual shelter components were simultaneously in test at both Eglin and Kirtland. The 560th Civil Engineering Squadron erected the test structures at Field 2 and trained men to erect the shelters in Vietnam. As of Concrete Sky III in January 1968, the Air Force Weapons Laboratory at Kirtland took on ordnance testing for the shelter, with physical testing at the UTTR (see Volume II, Chapters 6 and 8). The next two phases, IV-V, completed experimentation for the first-generation Concrete Sky shelter. Phases VII and VIII offered further refinements through munitions tests at Holloman Air Force Base and again on the UTTR.

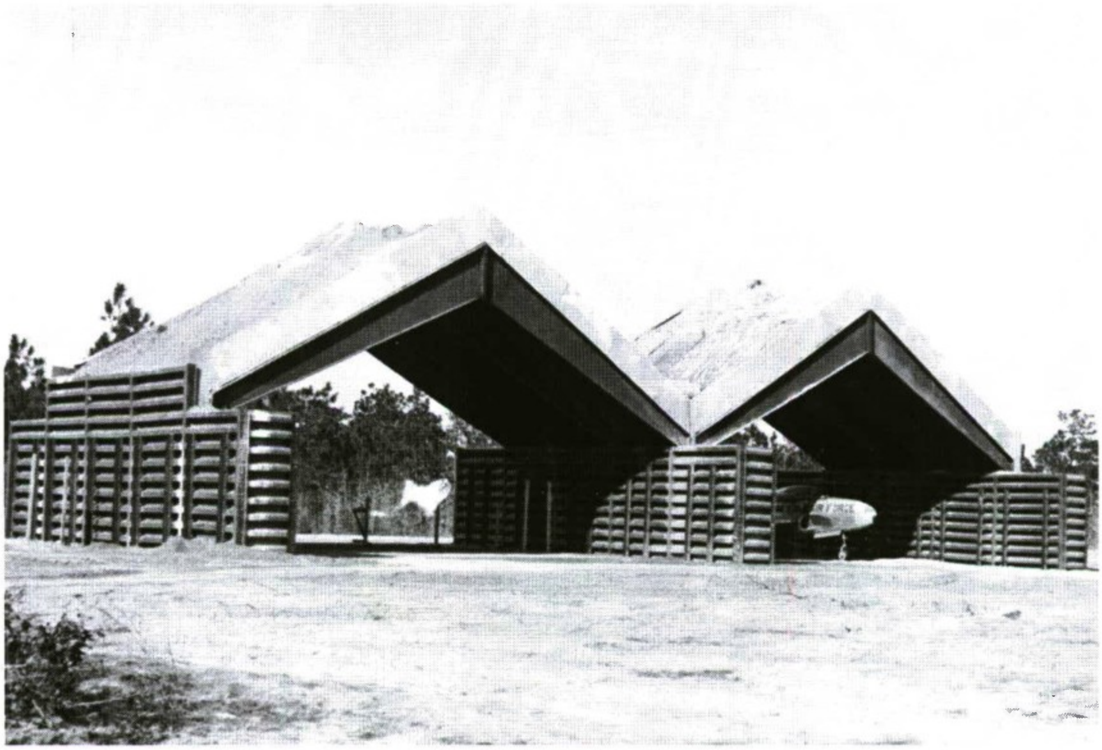

Plate 55: Marwais Steel Company. Aircraft Shelters at Site C-2 near Field 2, Eglin Air Force Base, October-December 1967. (No longer extant.) In *History of the 560th Civil Engineering Squadron (Heavy Repair) (TAC) 1 January – 30 June 1968*, volume 3.

The Air Force built first-generation Concrete Sky shelters for at least two very large programs overseas during the late 1960s into the early 1970s—the first of which was for Vietnam. The Tet Offensive, coupled with the six-day Israeli war, had greatly enhanced the Department of Defense's awareness of the need for protective construction. First-generation Concrete Sky for Vietnam resulted in an aircraft shelter formed from a steel arch, with a poured concrete cover 18 inches thick. A freestanding rear wall added protection and included a jet exhaust opening. Typically, the Air Force erected these shelters with some low revetment along the sides, electing to fit only a small number with front armored doors. Most shelters stood open, front and rear. Red Horse completed the final first-generation Concrete Sky shelter in Southeast Asia in early 1970 at Tuy Hoa. The program had added nearly 400 of these shelters to the existing revetments at air bases. While the focus was on protective construction for Vietnam, the TAB VEE shelter program stalled. The Air Force did not begin construction for TAB VEE until 1968. The double-corrugated steel shell for the TAB VEE shelters was in accelerated production before the close of the year, with manufacturers producing 35 shelters per week in double shifts. The Air Force initially erected the shelters in Vietnam, but also procured TAB VEE shelters for Korea and planned them for Europe. Almost 400 shelter shells were also set aside in War Readiness Materiel (WRM) storage at the Air Force Logistics Command (AFLC) depot bases of McClellan in California and Tinker in Oklahoma. By late 1968, the United States Air Forces in Europe (USAFE) also made substantial distinctions between the shelter program underway in Vietnam and Asia, and that beginning in Europe.

TAB VEE became a NATO effort, planned at 342 hardened aircraft shelters. The program also included dispersal pavement for the parked aircraft and protective construction for other types of facilities. From mid-June 1969 forward, TAB VEE became complicated. Multiple governments were involved. In addition, TAB VEE absorbed ongoing design and engineering improvements. By the close of that year 180 shelters were in place in Europe, with others planned for the Middle East. The Concrete Sky shelters totaled 1,500 in Vietnam, Korea, and Europe as of January 1970. The Air Force erected more than half of these with 15 to 18 inches of concrete cover. By the end of 1971, USAFE finished 360 shelters in Europe and the Middle East, with 18 in active construction. The comprehensive TAB VEE program cost stood at $95.5 million. Completion of the TAB VEE program lengthened, in part due to the addition of armored doors for the aircraft shelters and construction of ancillary facilities. Front closure for the European shelters was a serious concern in 1970, stimulating more design modifications. (During this same period, the shelters erected in Korea featured ballistic nylon closures.) Concrete Sky VIII of 1969 had partially tested prow-shaped doors that were recessed inside the shelter. Late in 1969, too, the Directorate of Civil Engineering initiated studies toward the next-generation shelter planned for the F-111 and the F-4.

At Eglin, tests for Concrete Sky VI moved from Field 2 to Field 7 in 1968-1973. An isolated shelter erected on Range C-52E also appears related to the Concrete Sky VI program. USAFE had proposed an alternate to the first-generation, concrete-covered steel arch shelter of Concrete Sky, even as the shelter went in place for TAB VEE. The "improved" USAFE shelter featured "quarter-circle arch segments joined at the top of the shelter and arch ribs joined to adjacent ribs by circumferential joints extending around the shelter perimeter." For Concrete Sky VI, the Air Force Weapons Laboratory at Kirtland contracted with the architectural-engineering firm Holmes & Narver of Los Angeles to design the hardened rear wall and exhaust system. The 557th Civil Engineering Squadron erected 12 improved USAFE shelters in a dispersal layout for an AFSC test program at Field 7 (today's Range B-12) (see Plate 44). Plans of 1972 called for "four precast concrete actual shelters, eight dummy shelters, and 3500 LF [linear feet] of concrete taxiway." The single shelter on Range C-52E is also of approximate 1972 construction, with selected differences. This shelter featured a double layer of reinforced concrete, rather than single as at Field 7 and its capstone treatment was peaked rather than flat. During the final years of the Vietnam War, the Directorate of Civil Engineering moved toward the design and engineering of a true second-generation aircraft shelter—Concrete Sky X, with the

goal of hardening against nuclear effects. Preliminary test efforts focused at the Air Force Weapons Laboratory at Kirtland for Concrete Sky VIII and IX (see Volume II, Chapter 8). As Concrete Sky X unfolded, Eglin retained the overall responsibility for the project. In late 1971, a six-man team from the Civil Engineering Center under AFSC at Wright-Patterson flew out to Cannon Air Force Base in New Mexico for tests of a shelter shell there. The Concrete Sky X shelter, described as a second-generation shelter, was about twice as wide as the previous Concrete Sky shelter built for Vietnam and TAB VEE. Concrete Sky X accommodated a variety of aircraft, with design efforts focused at first on the F-111. At Cannon, the AFSC team used a large machine "capable of reshaping existing shelter steel to the required larger radius." The Air Force completed preliminary designs for the second-generation shelter during early 1972. The immediate intent was to erect 24 steel shelters, without concrete cover, for the F-111 at four SAC bases. This figure climbed to six bases as SAC built out the program. As of about 1973, AFSC transferred Concrete Sky X responsibility to the Air Force Civil Engineering Center at Tyndall Air Force Base in the Florida panhandle to the east of Eglin. The Civil Engineering Center itself moved from Wright-Patterson to Tyndall at this same time. AFSC erected a test Concrete Sky X shelter at Tyndall in 1974. Eglin continued to be involved, with major responsibilities even after this date.

As of 1974-1976, all efforts turned toward true hardening. A third-generation program, Distant Runner, was underway simultaneously with continued construction for Concrete Sky X and upgrading for TAB VEE first-generation shelters at bases all over the world. AFSC installations contributing to the project were Eglin, Kirtland, Hill, and Tyndall (see Volume II, Chapters 6 and 8). Leo A. Daly, the architectural-engineering firm for the SAC alert moleholes and Headquarters SAC underground command posts of the 1950s and 1980s, designed the shelter for Distant Runner. During 1977, NATO planned to double the number of its protective aircraft shelters through second- and third-generation construction. The expansion of the program would take the total number of shelters to nearly 800. At the opening of 1979, 497 hardened aircraft shelters were operational in NATO countries. Of these, the TAB VEE shelters totaled 396—many augmented with upgrading. At this same time, the Engineering and Services Laboratory at Kirtland began a study for electromagnetic pulse (EMP) hardening of tactical aircraft shelters, and Tyndall conducted a second phase for an aircraft shelter upgrade. Through Distant Runner, new hardened aircraft shelter designs and variations for the third-generation program continued into 1981. Distant Runner involved multiple classified tests on the UTTR and at several locations in New Mexico. Distant Runner included designs for shelters tailored to the TR (tactical reconnaissance) -1 spy plane and the E (electronic [radar]) -3A Airborne Warning and Control System (AWACS). Yet another upgrading, the Weapons Storage and Security System (WS^3), integrated nuclear weapons storage compartments below the floors of earlier generation shelters. The Air Force sustained buildout for the entire program into the early 1990s, with Project Reliance closing down the program in 1992 (see Volume II, Chapter 8).

Simultaneously with the beginnings of the first testing for Concrete Sky, a number of limited-war initiatives were also in progress at Eglin to support Air Force and Army efforts in Vietnam. As of 1967, the 560th Civil Engineering Squadron built several experimental structures at Field 2, complementing its efforts toward prototype protective aircraft shelters on site or nearby (see Plate 55). The 560th Civil Engineering Squadron concentrated its efforts on the development of prefabricated units with the potential for streamlined shipment and quick erection in Vietnam. In addition, the work at Field 2 supported the TAC test and evaluation for a mobilization base that could be shipped anywhere in the world on 24 hours notice. First called "Base Z" and later "Bare Base," this type of tactical combat installation was also capable of beginning operations within eight hours after setdown. By 1969-1970, Bare Base included multiple modular or expandable units packaged as containers and designed to replace personnel tents and aircraft hangars where deployed. Bare Base

prototype aircraft shelters in test at Eglin included multiple types of structures. Structural systems and sheathing were critical. Engineers experimented with laminated wood arches and aluminum purlins, aluminum-tube arches (the Birdair hangar), and "wide-flange aluminum beams coupled with sandwich panels covered with aluminum to provide a rigid envelope" (the University of Cincinnati hangar). Sheathing was most often plywood or fabric. The Birdair hangar (Plate 56) had many uses over the extended period of the Cold War, not only in theater-of-war situations, but also when emergencies required it. At Tinker Air Force Base, AFLC used 10 of the hangars in 1984 to function as temporary shelters after a major fire (see Volume II, Chapter 13). Birdair Structures, Inc., of Buffalo, had previously designed and engineered the prototype for an inflated spherical dome for Army missile maintenance in 1958-1959. The Pentadome had consisted of one 150-foot-diameter inflated vinyl-coated nylon dome, surrounded by four 100-foot-diameter similar domes. The Air Force had exhibited the Pentadome at Andrews Air Force Base (the headquarters location for ARDC) in 1959.[37]

The 560th Civil Engineering Squadron erected varied test structures, both prefabricated and of other ephemeral types, at Field 2 between 1966 and 1968. The largest project on site was Concrete Blue (TAC Test 67-238), initiated in mid-1967 to test prototype "pre-engineered" 80-man dormitories. The dormitories were to be "modest in scale; truly relocatable; [of] United States manufacture; quickly attainable; easily erectable by Civil Engineer Prime Beef [Base Engineering Emergency Forces] or Red Horse forces; ...easily dismantled, repackaged for shipment and use elsewhere; [and] so designed as to incorporate latest techniques, materials and production methods of the United States

Plate 56: Birdair Structures, Inc. Birdair Hangars, Tinker Air Force Base, Oklahoma, 1984. Courtesy of the History Office, Tinker Air Force Base.

industry." By the close of 1969, the Air Force expended over $33 million for the procurement of Concrete Blue dormitories, with extensive use in South Vietnam and Korea. At Field 2, the 560th Civil Engineering Squadron erected four prototype two-story dormitories in August 1967. Modulux Incorporated of Newark, California, manufactured two different dormitories for testing at Eglin, while Custom House Camp Buildings and National Mobile Leasing Incorporated manufactured one each. All were steel frame in their basic structure. The Modulux buildings featured a double-layered plywood wall system, with one-and-one-half inches of fiberglass insulation, and interior fiberglass panel finish. The Custom House Camp dormitory was of similar construction, but had an exterior fiberglass finish. The National Mobile dormitory was essentially a paper building. The structure employed honeycombed paper panels impregnated with Kraft phenolic resin sandwiched between very thin sheets of aluminum. The 560th Civil Engineering Squadron erected the four structures in a row, side by side (Plate 57). In an unrelated event of less than a decade later, Eglin's Field 2 would serve as one of four American major Vietnamese refugee processing centers after the war ended. More than 10,000 Vietnamese lived in a tent city of multiple blocks between May and mid-September 1975 (Plate 58).

During 1967-1968, the 560th Civil Engineering Squadron experimented with rapid runway repair, comparing "fast fix concrete" to Portland cement concrete. The Air Proving Ground Center had initiated testing for the rapid repair of bomb-damaged runways four years earlier in February 1963 as Project 5968W2. Test personnel used the north-south strip of the runway at Field 8 for the effort. Project 5968W2 concluded that men could not repair a bomb-damaged runway "within four hours in a tactical situation using existing procedures." Headquarters Air Force authorized a follow-on project, 1375W1, at Field 8 in October 1963. The Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi, provided technical assistance. Again the test location was Field 8. Tests for Project 1375W1 ran between April and December 1964. For runway repair in a theater-of-operations situation like Southeast Asia, the efforts managed by the Air Proving Ground Center in 1964 were reminiscent of those in World War II (with major runway experimentation conducted by Eglin during the early 1940s), but included a greater emphasis on heavier runway substructure. As of January 1967, the 560th Civil Engineering Squadron again tested repair mixes for bomb-damaged runways, first planning to use Field 8 but finally deciding to move to Field 2. By this date, AFSC had contracted with the Western Company of Richardson, Texas, to develop a fast-fix cement. Personnel tried two Western Company fast-fix cements at Eglin, with engineers at the Navy's civil engineering center at Port Hueneme, California, participating in the testing at the end of the year. Efforts of the 560th Civil Engineering Squadron continued in 1968, when the squadron conducted a comparative test of Fast-Fix to Portland cement for durability at Field 2. Simultaneously, the Air Force furnished the fast-settling cement to bases in Southeast Asia, Korea, and West Germany for operational suitability testing. By 1969, the Air Force Aero Propulsion Laboratory at Wright-Patterson had two alternate repair materials in test, Fast-Fix (gypsum) cement and a "woven roven [woven together, twisted strands of] glass fiber impregnated with an organic polyester resin." Laboratory personnel looked at the differences between an inorganic mix and an organic one. During late 1969 into 1970, runway repair testing at Eglin led to the development of a standard Bomb Damage Repair kit, including a patch of aluminum landing mat and fast-fix cement. Rapid runway repair tests were ongoing, under the name Concrete Beet (Base Engineer Emergency Test.)[38]

During the 1970s also, the Armament Development and Test Center at Eglin received the guided missiles mission to alleviate an overload within Aeronautical Systems Division (ASD) at Wright-Patterson. AFSC shifted developmental planning for "air launched, nonnuclear tactical air-to-ground, tactical air-to-air, and air defense missiles" to the armament center at Eglin. As of 1972, missiles in development and test at Eglin included the AIM (air interceptor missile) –9L (Sidewinder), the AIM-7F (Sparrow), the AGM (air-to-ground Missile) – 45A (Shrike), the AGM-78 (a standard

Plate 57: National Mobile Leasing, Inc. (1), Custom House Camp Buildings (1), and Modulux, Inc. (2) [left to right]. Concrete Blue Relocatable Dormitories, Field 2, Eglin Air Force Base, autumn 1967. In *History of the 560th Civil Engineering Squadron (Heavy Repair) (TAC) 1 July – 31 December 1967.*

Plate 58: Vietnamese Refugee Processing Center, Field 2, Eglin Air Force base, May-September 1975. In *History of the Armament Development and Test Center 1 July – 31 December 1975*, volume 6.

antiradiation missile [ARM]), and the AIM-4H (Falcon). ASD also transferred AGM-62 (Walleye) to Eglin. The Navy managed each of these missile programs, with the exception of the AIM-4H. The Air Force, however, was in the process of modifying these Navy weapons systems for Air Force use. The Hellfire missile was also in test at Eglin, on Ranges C-7, C-7A, and C-72. The Eglin target areas were part of the Hellfire Production and Verification Test Facility to evaluate production samples of the missile. Range C-72 included three laser-designated targets for the Hellfire. Developed by the Army's Missile Command at the Redstone Arsenal in Huntsville beginning in 1971, the Hellfire is a laser-guided air-to-ground missile. The Army conceived the missile as an antitank weapon to be carried on helicopters. During 1983-1984, the Secretary of Defense authorized the Hellfire for NATO deployment. The Army deployed the Hellfire significantly at the end of the Cold War in Operations Desert Shield and Desert Storm in the Middle East.[39]

During the late Cold War, Eglin continued to sustain a variety of tenant and specialized missions. As of 1968-1969, AFSC established a Red-Blue Team testing structure to improve Air Force capabilities in electronic warfare. Important test systems included sensors, communications, and radars, as well as ground- and air-space command and control systems. The RADC at Griffiss was prominently involved in the electronics test programs. Gaining an understanding of foreign technologies was of equal emphasis. Red and Blue teams "played against each other in 'move' and 'countermove' actions directed primarily toward technical characteristics and performance that affected the capabilities of opposing electronic equipments or systems." In November 1975, TAC also initiated a "Red Flag" exercise through the command's Fighter Weapons Center at Nellis Air Force Base near Las Vegas, Nevada. A 3.5-million-acre range supported TAC's Fighter Weapons Center for tests of combat readiness. TAC conducted Red Force and Blue Force activities at Nellis, with Red teams simulating the enemy and Blue teams acting as the defending nations. Red Flag exercises tested American and Allied / NATO air and ground forces for actual war, with six-week exercises up to six times a year. Red Flag served as surrogate combat. Red Flag exercises at Nellis led to complementary Blue Flag exercises at Eglin as of March 1977. Blue Flag trained more than 40,000 personnel from 14 nations between the late 1970s and the end of the Cold War. Like Red Flag, Blue Flag continues as a major Air Force program in 2000. In 1980-1981, the Tactical Air Warfare Center at Eglin inaugurated Green Flag exercises. Green Flag functioned as a component of Red Flag at Nellis. TAC initiated Green Flag as a "live-fly electronic combat exercise"—in effect, a Red Flag with an emphasis on electronic combat. Again, the RADC was a key exercise participant. Eglin's Green Flag "would become the most comprehensive electronic combat exercise in the world."[40]

During the final phase of the Cold War, Eglin ran multiple tests on its ranges. The installation continued to use infrastructure and target complexes specific to earlier periods, simultaneously adding and modifying test compounds, ancillary structures, and instrumentation when pertinent to testing and training missions. At the end of the war, the 10 auxiliary airfields at Eglin largely sustained their lengths and widths of World War II (Fields 4, 5, 7, and 8) and the early 1950s (the remainder, each having at least one runway of 7,500-8,000 feet, with Field 9 possessing the longest runway at 9,600 feet). Eglin's ranges continued to offer many individual test locations, in a variety of environments including "jungle conditions, rolling hills, heavily forested areas, cleared flat areas, and water areas." From the late 1960s forward, infrastructure across the ranges supported sophisticated categories of testing for Air Force developmental and operational agencies. The major test categories included electromagnetic environments, general instrumentation support, land range test areas, and smaller, specialized land range test areas, sometimes seasonal in nature.[41]

Key Associated Architects and Engineers

Architects and engineers of major significance who designed buildings and structures at Eglin Air Force Base during the Cold War, or were critical to testing programs at the installation, are numerous.

A number of firms are discussed in Volume I or in other chapters of Volume II, as noted below. Architects and engineers working at Eglin included:

- Black & Veatch, of Kansas City;
- Burns & Roe, of New York (Volume II, Chapter 1);
- Leo A. Daly, of Omaha;
- Holabird, Root & Burgee, of Chicago (Volume I, Parts III and IV);
- Holmes & Narver, of Los Angeles;
- Kellex (Vitro) Corporation, of New York;
- L.P. Kooken, of Baltimore (Volume I, Part II);
- Kuljian Corporation, of Philadelphia (Volume II, Chapter 3);
- Ralph M. Parsons, of Los Angeles (Volume II, Chapter 3);
- Fred N. Severud, of New York; and,
- J. Gordon Turnbull, of Cleveland (Volume I, Part III).

Black & Veatch

Black & Veatch began its work for the United States government with architect-engineer services at Los Alamos in 1946. Partners Ernest Bateman Black and Nathan Thomas Veatch, Jr., had founded the firm in Kansas City in 1915. During World War I, Black & Veatch was among firms selected to provide the engineering design for Army camps. During 1964-1952, the firm established itself as the undisputed leader in design of special weapons storage facilities, storage magazines, and associated shops used by SAC and ADC. Black & Veatch was responsible for the design and engineering of the Q Areas and their associated stockpile sites—which were the first storage structures for components of the atomic bomb. The firm also converted the Army Ordnance Plant in Burlington, Iowa, to a nuclear components plant. Black & Veatch designed multiple missile checkout and assembly structures, missile storage facilities, and heightened military security systems throughout the Cold War. Today, Black & Veatch continues as a leader in the design and engineering of advanced technology facilities, hardened structures, and security design. The firm's expertise extends to radioactive and electromagnetic environments, clean rooms, weapons research facilities, laboratories, nuclear-chemical waste treatment, blast-resistant design, blast-containment design, and munitions storage magazines.[42]

Leo A. Daly

Leo A. Daly, like Black & Veatch, originated in 1915. The firm undertook a variety of civilian work during its first years, receiving national recognition for the design of the Boys Town campus in Omaha during the 1930s. Similar to many firms, Leo A. Daly undertook defense work during World War II, but only during the 1950s did this sector of its business became major. In 1952, Leo A. Daly, Jr., took over the firm. As of mid-decade, Leo A. Daly established itself as the architectural-engineering firm most often hired by SAC for complex building programs across the command. Noteworthy examples of SAC-related designwork include the alert bomber facilities of 1958 (moleholes and alert aprons), the two underground command posts at Offutt Air Force Base in Omaha of the middle 1950s and the middle 1980s, assembly buildings for Minuteman during the early 1960s, the final iteration of the Concrete Sky hardened aircraft shelter in the middle 1970s, and a missile maintenance facility for the Peacekeeper in the early 1980s.[43] The Daly firm also designed more routine buildings for the command, including its main chapel of the middle 1950s at Offutt and its first museum near the base of the early 1970s. Leo A. Daly III headed the firm as of 1981. A last notable commission associated with SAC is the new museum for command, located between Omaha and Lincoln and executed in partnership with Butler Manufacturing of Kansas City during the late 1990s.[44]

Holmes & Narver

Information on the founding of Holmes & Narver remains minimal. The firm existed by 1950, and was responsible for critical work for Los Alamos, the Sandia Laboratory, and the Department of Defense. Holmes & Narver handled the structures and instrumentation program for Operation Greenhouse, an elaborate nuclear test in the Marshall Islands during April and May 1951. The final shot for Greenhouse was the first successful thermonuclear explosion in the world. David Narver Jr. served as project leader for the Holmes & Narver team, with Sandia's project leader, Luke Vortman, assigned to the Holmes & Narver office in Los Angeles to plan the structures program for Greenhouse. The program included 900 electrical recording gauges and 500 self-recording gauges on 18 different types of mounts. Greenhouse also featured Sandia's "House of Correction," a model of a Russian apartment building calibrated for the test (see Volume I, Part III). Four Holmes & Narver employees who worked on Greenhouse transferred to Sandia after the tests.[45] In the middle 1950s, the Air Force hired Holmes & Narver to conduct site studies at Holloman Air Force Base toward the ICBM test launch installation that would evolve as Vandenberg Air Force Base after 1956. Holmes & Narver next designed and engineered the Atlas launch complexes at Vandenberg, following upon the work of Daniel, Mann, Johnson & Mendenhall (DMJM) for the Thor complexes on base. In 1980, the firm designed the Rail Transfer Facility for the MX (missile experiment) ICBM at Vandenberg. The Air Force incorporated the facility into Rail Garrison at the end of the decade (see Volume I, Part I). In the later Cold War, too, Holmes & Narver designed and engineered the third-generation hardened aircraft shelters tested through the Air Force Weapons Laboratory. Today, the firm offers a variety of services, with commissions ranging from design for maximum security prisons, to wastewater treatment plants, power generation systems, rail and highway projects, and airport expansion programs. Military-related projects include the recabling of infrastructure for the Sandia National Laboratory at Kirtland Air Force Base and ground facilities for satellite telecommunications systems.[46]

Kellex (Vitro) Corporation

The Kellex Corporation was a subsidiary of the M.W. Kellogg Company of New York. M.W. Kellogg organized Kellex in 1943 to engineer a specialized gaseous diffusion plant needed to separate uranium isotopes (fissionable U-235 from inert U-238) for the manufacture of an atomic bomb. Built as a part of the Manhattan Project, the diffusion plant was one of several industrial structures sited in the Clinton Engineering Works area of the Oak Ridge reservation west of Knoxville, Tennessee. The Clinton Engineering Works complex included three major industrial plants for uranium isotope separation. The Kellex gaseous diffusion plant and its power station was a $534,000,000 effort. At the close of World War II, *Engineering News-Record* described the Kellex plant at the Clinton Engineering Works as "one of the largest and most complex plants in industrial history." Design and engineering of this first Kellex project had required over 20,000 pages of architectural-engineering specifications, 12,000 drawings, and 10,000 pages of operating instructions. During the late 1940s, Kellex continued to design and engineer special laboratories, including ones of "hot" type. The firm was also involved in the engineering of the first nuclear power reactors and chemical processing plants for the Atomic Energy Commission (AEC). Kellex was closely tied to military-industrial armament community at the outset of the Cold War.[47]

Fred N. Severud

Immigrant Fred Severud was of international importance as an engineer, and stands apart from others associated with the design of buildings and structures at Eglin. Severud achieved renown for addressing problems of difficult site conditions, new structural materials, and blast-proof construction for the post-atomic world. He was also well known for his abilities to engineer structural solutions

appropriate to the increased spans and heights of modern buildings. Severud was born in Norway and educated as a civil engineer at the Institute of Technology in Trondheim, where he received his degree in 1923. After completing his education, Severud immediately immigrated to New York. During the 1930s, he established a reputation for innovative structural modifications applicable to buildings that had developed serious problems. In the next decade, Severud was best known for his high-rise hospital and multiunit housing construction and, by the middle and late 1940s, for his focus on the challenges of longer clear spans for aircraft hangars. During the 1950s, he solidified his reputation for understanding the long span. In this decade, too, Severud completed an early detailed analysis of the conditions of atomic blast and their relationship to effectively blast-resistant construction. With regards to the long span, Severud published a key article in *Architectural Record* in April 1947 that analyzed the pros and cons of all major structural solutions for the long-span aircraft hangar to date. The cable-supported roof, in particular, was a Severud solution adapted for a number American structures from this period forward. Important buildings and structures for which Severud executed the engineering included the Yale University hockey rink; a pavilion in Raleigh, North Carolina; Madison Square Garden in New York; the Place Villemarie Center in Montreal; the City Hall complex in Toronto; and, the Gateway Arch in St. Louis.[48]

---

[1] Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 of *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). Information contained in the volume includes: source of the installation's name; current and past names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base.

[2] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001). The author provides an expanded discussion of Eglin Cold War history in this study. References to *Eglin Air Force Base, 1931-1991* given below are generally to the sections of text that look at the material in greater depth. The author has not repeated reference citations from *Eglin Air Force Base, 1931-1991* in the notes below. Readers can ascertain all original sources, however, through cross-referencing the text and endnotes provided in *Eglin Air Force Base, 1931-1991* with the materials discussed in this chapter. Any research not included in *Eglin Air Force Base, 1931-1991* is documented with new endnotes, as appropriate.

[3] *Ibid*, 131-134.

[4] *Ibid*, 23-25. Also, *passim* for examples of "Category" tests during the Cold War.

[5] *Ibid*, 87-97, 121-128.

[6] Naming of the V-1 is somewhat complicated. The "V" is often transcribed as Vergeltung ("vengeance") from a German Army usage. However, Vergeltung is a retroactive naming of a preexisting German weapons group. Early in World War II, most of the V-series of weapons were known as A-series weapons. The V-2, for example, had been the A-4. "A" derived from Aggregat, a term taken by German scientists from the English "aggregate" to describe the rockets in progress during the early 1930s. The German Air Ministry officially designated the V-1 as the Fi-103. The "Fi" derived from the small aircraft company making the pulsed-jet weapon, Fieseler. See Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (Cambridge, Massachusetts: Harvard University Press, 1995), 147-148.

[7] Karen J. Weitze, Lori Lilburn, Christy Dolan, and Angie Gustafson, *Eglin Air Force Base Inventory of Historic Properties FY2000*, volumes 1-2 (San Diego: EDAW, Inc., for Air Force Materiel Command, September 2001).

[8] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 80-87; Mueller, *Active Air Force Bases*, 1989, 138-139.

[9] The author has field-checked the hangars at Eglin and at Travis. Good sources, however, indicate the historic presence of two identical hangars at Norton. Current status for the Norton hangars is unknown.

[10] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 97-103.

[11] The "Ocala Bombing Range" is probably a reference to the Ocala Tract near Sumner and Cedar Keys on the west coast of central Florida. The Army Air Forces used the land for jungle warfare testing, running tests for defoliation (by aircraft spraying), and bomb drops (Napalm and white phosphorous during World War II). The

tract was originally part of the Ocala National Forest. The legal status of the Ocala Bombing Range is undetermined for this study. The range may have been a small attached installation to Eglin. See *ibid*, 79.
[12] *Ibid*, 115-121.
[13] Air Research and Development Command, *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 1, 41-50.
[14] The Kellex Corporation, *Study of Instrumentation and Facilities for the Air Materiel Armament Test Center*, Final Engineering Report for Job-30, Contract AF 33(038)13892 (New York: The Kellex Corporation: 26 December 1950), 60.
[15] *Ibid, passim*; and, Karen J. Weitze, Carrie Gregory, and Lori Lilburn, *Eglin Air Force Base Inventory of Historic Properties 2001-2003, Part III*, Draft (San Diego: EDAW, Inc., for Air Force Materiel Command, February 2003).
[16] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 128-152, 232-235, 267-268.
[17] *Ibid*, 153-160.
[18] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 160-162.
[19] Air Research and Development Command, *History of the Air Force Cambridge Research Center 1 January – 30 June 1953*, volume 18, part 1, 258.
[20] Karen J. Weitze, Carrie Gregory, Lori Lilburn, and Angie Gustafson, *Eglin Air Force Base Inventory of Historic Properties 2001-2003, Part I*, Draft (San Diego: EDAW, Inc., for Air Force Materiel Command, February 2002), "Building 123."
[21] Air Proving Ground Command, *History of the Air Force Operational Test Center 1 July – 31 December 1954*, volume 1, 1-2, 41-44, 84-98.
[22] For a clear breakdown of the lineage of the letter meanings in radar designations see Fritz Gross, W.M. Hall, and D.K. Barton, "Detection and Tracing Systems: An Historical Overview," *Electronic Progress* 16, 3 (Fall 1974): 2-11. For example, in "AN/FPS" the "AN" is a joint military designation for "Army-Navy," while "F" indicates "fixed;" "P" indicates "radar" (the type of electronic equipment); and, "S" indicates "detection." Some radar and related equipment designations of the early Cold War are difficult to decipher today due to the obsolescence of the electronics type, and subsequently a disappearance of the terminology.
[23] Air Force Systems Command, *History of the Air Proving Ground Center 1 July – 31 December 1961*, volume 4, I-23 – I-27.
[24] Western Electric Company, *DEW East Completion Report*, 30 March 1962, 1-7, 34-35.
[25] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 204-224.
[26] *Ibid*, 168-189.
[27] Yonge, Look & Morrison, "Inland Nike Site Facilities," set of seven drawings, 1 November 1955.
[28] E.C. Itschner, "Missile Construction for Security," *The Military Engineer* 51, 342 (July-August 1959): 257-262.
[29] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 257-258.
[30] *Ibid*, 255-257.
[31] *Ibid*, 217, 276.
[32] *Ibid*, 224-230.
[33] *Ibid*, 261.
[34] Building 8970 is highly unusual. Its core has the appearance of a stockade. A sustained story among men at Building 9300 adjacent suggests that "Germans" may have constructed Building 8970. See, Weitze, Gregory, and Lilburn, *Eglin Air Force Base Inventory of Historic Properties 2001-2003, Part III*, Draft, 2003.
[35] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 267-275.
[36] *Ibid*, 230-254, 304-310.
[37] John E. Quaile, "New Military Techniques, II. Missile Aids, Communications, Rocket Photos," *The Military Engineer* 51, 343 (September-October 1959): 376-377.
[38] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 261-267, 281.
[39] *Ibid*, 257-260, 312-315.
[40] *Ibid*, 297-298.
[41] *Ibid*, 311-320.
[42] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 106.

[43] Karen J. Weitze, *National Register of Historic Places Evaluation Peacekeeper Rail Garrison Complex Vandenberg Air Force Base* (Austin, Texas: Dames & Moore, Inc., for Air Force Materiel Command, April 1994), 28.
[44] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 124-127.
[45] Necah Stewart Furman, *Sandia National Laboratories: The Postwar Decade* (Albuquerque: University of New Mexico Press, 1990), 580-585.
[46] Information about Holmes & Narver derived from the author's files, and as posted at www.hninc.com.
[47] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 134.
[48] *Ibid*, 100-101.

Chapter 5: Hanscom Air Force Base

Historic Missions of the Cold War

Hanscom Field originated as an auxiliary airport for Boston in mid-1941, sustaining an Army presence beginning in July 1942. The airfield underwent a series of name changes during its history that reflected its role as a civilian airport, a military post, and a location of major research and development (R&D) laboratories. In addition, the installation's Cold War evolution began in downtown Boston in leased facilities, as a field office for laboratories in New Jersey. Its early core of electronics specialists largely derived from personnel who had transferred to the Army Air Forces from the Radiation Laboratory of the Massachusetts Institute of Technology (MIT) of World War II. Even after the installation became an Air Force center under Air Materiel Command, the physical location of the laboratories remained in Boston until a suitable larger site could be found, acquired, and readied for occupancy. Not until the laboratories were subsumed under Air Research and Development Command (ARDC) in the early 1950s did they relocate to what is today Hanscom Air Force Base. The lineage of names and sites for the installation is further complicated through the prominence of its dominant laboratories. In the years prior to a physical location at a military airfield, the laboratories were known only as the field office for other facilities and then as the Cambridge Research Laboratories. Subsequently, the Cambridge Research Laboratories went through several name changes, alternating between the use of "Laboratories" and "Center." Once at Hanscom, the laboratories became closely affiliated with other laboratory clusters brought to the airfield and managed under ARDC as an installation—although the clustered facilities did not become a formal "Air Force Base" until the middle 1970s. When the Cambridge Research Center moved from downtown Boston to the former World War II airfield northwest of the city, the installation was formally designated Laurence G. Hanscom Field. In the middle and late 1970s, the Air Force changed its name and status to Laurence G. Hanscom Air Force Base and subsequently Hanscom Air Force Base. As a convention for simplifying discussion and in recognition of the Air Force common nomenclature for the base, this chapter refers to Laurence G. Hanscom Field as "Hanscom Field" and Laurence G. Hanscom Air Force Base as "Hanscom Air Force Base."[1]

As of 1943, Bedford Army Air Field had become a government facility, although the airfield would continue to have a civilian component after World War II (and does in 2000). For two years prior to this date, the airfield had operated as Laurence G. Hanscom Field (and was alternately known as the Boston Auxiliary Airport). During the Second World War, activities at Bedford Army Air Field were relatively minimal. The Army tiered the installation successively to Westover Army Air Field (western Massachusetts), Grenier Army Air Field (New Hampshire), and Bradley Army Air Field (Connecticut). By 1944 the base was inactive, and MIT built a test hangar and radar communications compound on site. The same year, I Fighter Command established a Fighter Control Center at the base, one of a small number planned for the northeastern United States (see Volume I, Part IV). The two missions of 1944 foreshadowed a key role for the airfield in the development and test of air defense networks during successive decades of the Cold War. As of 1945, Bedford Army Air Field continued its link to MIT when the Radiation Laboratory there disbanded and chiefly became absorbed into the Cambridge Field Station of the Watson Laboratories, an electronics test facility of Air Technical Service Command (subsequently, Air Materiel Command). During the late 1940s and early 1950s, while the Air Force decided on a permanent location for the Cambridge Field Station, Bedford Air Field (subsequently, Hanscom Field) returned to fully civilian status. The airfield was known as Hanscom Airport (1947), Bedford and Hanscom Fields (1948), and Laurence G. Hanscom Field (1951-1974). The latter name continued after its change from a fully civilian airfield to one that combined civilian and Air Force use. Hanscom Field featured short runways, minimal hangars, and exclusively woodframe temporary buildings. After ARDC decided to locate the Cambridge Research Laboratories (soon, Cambridge Research Center) at Hanscom Field as of 1950, plans went forward to

establish a sophisticated complex of science laboratories at the former Army Air Forces base. MIT's Project Lincoln led to the siting of the Lincoln Laboratory at Hanscom, with the Semi-Automatic Ground Environment (SAGE) project one of the most important early air defense efforts. As of the middle 1950s, the Cambridge Research Center (and its follow-on laboratory organizations) became a premier location for Air Force air defense systems, electronics, and geophysics R&D. The Air Force designated the installation as the Laurence G. Hanscom Air Force Base in late June 1974 and as Hanscom Air Force Base in January 1977. The laboratories defined the base through the end of the Cold War, and continue to do so today.

Primary Missions

The primary Cold War missions at Hanscom Air Force Base focused on electronics, air defense, and geophysics R&D under ARDC / Air Force Systems Command (AFSC). Missions included:

- development and test for air defense command and control, in conjunction with the Lincoln Laboratory of MIT;
- close intercoordination, and sometimes competition, with air defense and radar R&D conducted at the Rome Air Development Center (RADC) at Griffiss Air Force Base, New York;
- major program responsibilities for SAGE, the Back-Up Interceptor Control (BUIC) program, and the Joint Surveillance System (JSS);
- research and test toward airborne command posts and surveillance;
- key development responsibilities for long-range and large phased-array radars;
- upper atmosphere and near-space studies, including balloon research and sounding rocket test packages;
- meteorology;
- participation in Air Force biological and nuclear weapons studies; and,
- sustained geophysics and electronics R&D.

Tenant Organization Missions

Hanscom Field (as of 1974, Air Force Base) operated chiefly as an R&D installation, with airfield missions typically supporting electronics testing. The base was not suitable to many of the major tenant missions often found across the Air Force during the Cold War. The single mission of this kind at Hanscom was:

- an alert ADC fighter-interceptor squadron (FIS), with the 49th FIS operational from late 1955 to mid-1959.

The 49th FIS additionally supported electronics testing at Hanscom for SAGE.

Chronology

The Air Force installation at Hanscom evolved from two predecessors of World War II: the airfield at Bedford, Massachusetts, and the research laboratories of two Boston universities contracted to the Office of Scientific Research and Development (OSRD). Airfield construction dated to mid-1941 for Laurence G. Hanscom Field, a facility also known as the Boston Auxiliary Airport. Laurence Gerard Hanscom was a prominent regional pilot and newspaperman who had died in a plane crash earlier that year. The airfield continued to function in a partial civil capacity as the Bedford Municipal Airport into 1943. Thereafter, the United States government operated the Bedford Army Air Field through

the war. An Army presence at the airfield dated to July 1942, when the nascent installation became the headquarters of the 79th Fighter Group. The physical infrastructure at the base featured several hangars for P (pursuit) -47 aircraft and a cantonment of temporary buildings. Bedford Army Air Field (Hanscom Field) initially reported to Westover Field to the west. Westover was an Army Air Forces base assigned to the First Air Force and responsible for training B (bomber) -24 crews. During October 1942 through May 1943, Bedford was a subinstallation of Greiner Field at Manchester, New Hampshire (today's Manchester Airport). The base next fell under Bradley Field in Connecticut for several months in mid-1943. Subsequently, the Army Air Forces reassigned Bedford Army Air Field to Greiner and then again to Westover. As of January 1944, the Army Air Forces placed the installation on standby status. In the autumn, Bedford Army Air Field became a test facility for radar and radio research underway at MIT and Harvard. The base had sustained its greatest activity levels during World War II in 1943, when it had hosted sequential fighter squadrons and an air defense wing.[2]

The 6th Air Defense Wing, at Bedford Army Air Field between late June and early August 1943, may have foreshadowed the Army's plans for a Fighter Control Center at the installation as of 1944. I Fighter Command had programmed nine Fighter Control Centers for the North Atlantic Coast from Maine to Virginia by December 1942, with the Massachusetts location shifting several times during 1943. The Bedford site was among I Fighter Command's final streamlined program of five locations. (The others were at Mitchel Field on Long Island; Fort Dix, New Jersey, adjacent to the later McGuire Air Force Base; Andrews Field outside Washington, D.C.; and, Langley Field, Virginia.) As air defense planning continued late in the Second World War, I Fighter Command subsequently downsized its command post web for the Northeast. In June 1944, I Fighter Command dismantled the two centers at Fort Dix and Bedford (leaving three for the North Atlantic)—just as MIT and Harvard adapted Bedford Army Air Field for radar test facilities. The Fighter Control Center was the origin of the Air Defense Control Center (ADCC) of the late 1940s, an air defense command post developed jointly through expertise within Air Materiel Command and Continental Air Command (CONAC), and one that led directly to SAGE (see Volume I, Parts III and IV). The Watson Laboratories in New Jersey, the Cambridge Research Center at Hanscom, and the RADC at Griffiss were the three Air Materiel Command (ARDC / AFSC) bases that would become most thoroughly involved in air defense R&D of the 1945-1991 years. ARDC / AFSC focused the command's efforts for SAGE and the follow-on program BUIC at Hanscom from 1952 into the late 1960s (see Volume I, Part IV).[3]

The Army Air Forces sustained no active mission at Bedford Army Air Field from late 1944 through disposal of the base on 8 March 1946. As of October 1944, coincident with the airfield's new role as a radar and radio research site for the electronics laboratories at MIT and Harvard, the Army transferred command for Bedford Army Air Field from the First Air Force at Westover to Air Technical Service Command at Wright Field in Ohio. Air Technical Service Command maintained jurisdiction of the installation until disposal. In November 1945, the command looked at Bedford Field as a probable location for an aeronautical research center modeled after the Hermann Göring Institute in Germany and one where the Army Air Forces could install German equipment confiscated at the war's end—a specific suggestion offered to Air Technical Service Command for use of the Bedford site by the British Royal Air Force (RAF). Bedford Field's proximity to Boston, and to the MIT and Harvard laboratories, presumably was the underlying rationale for this immediate post-World War II plan (see Volume I, Part II). While Air Technical Service Command continued to evaluate possible locations for what was first called an Air Engineering Development Center (AEDC) (a center that evolved into the Arnold Engineering Development Center in Tennessee), the federal government transferred Bedford Field to the Commonwealth of Massachusetts as of late August 1946. Once more foreshadowing the importance of future air defense R&D at Hanscom, Air Defense Command (ADC) filled the base host role during July and August 1946, and as of July 1947 the Air

Force leased the base for an air defense mission. In December 1948, the Air Force assigned Hanscom Field (a name change of June) to CONAC. An air defense mission continued to be the dominant activity at the airfield. In January 1951, Headquarters Air Force transferred Hanscom Field back to ADC. (The command change was really one in name only. ADC existed both before and after CONAC, and was subsumed within CONAC during the late 1940s.)

The Boston laboratories conducting electronics research for the OSRD during World War II were the Radiation Laboratory at MIT and the Radio Research Laboratory at Harvard. The federal government dissolved the OSRD immediately following victory in Europe and Japan, prompting the American military services to recruit personnel from the two laboratories. Air Technical Service Command sought people from the two former OSRD facilities for its electronics laboratories at Wright Field and at the Watson Laboratories in New Jersey. The immediate goal was to continue ground radar research at the Watson Laboratories and to complete key projects underway. Transfer of scientific staff and equipment, however, was daunting. The command instead decided to establish a new research facility, the Cambridge Field Station of the Watson Laboratories and established its location in downtown Boston. Air Technical Service Command intended to move the hired scientists assembled for its Cambridge Field Station from Boston to Wright Field once planning for R&D became further defined. From the beginning, scientists were not easily convinced that the Army Air Forces would offer a sufficiently intellectual environment, nor would have the desired funded resources. In addition, once the war was over competition for American scientists was high between universities and military service arms, as well as among industry and business. The decision to keep the Cambridge Field Station in Boston was a major determinant, with scientists strongly favoring the location due to the nearby technical libraries, professional associates, and cultural prestige. As of early September 1945, Air Technical Service Command had interviewed over 850 persons for possible employment at the electronics field station. Of those, about two-thirds submitted job applications. The retrieval of ORSD equipment from the MIT Radiation Laboratory proved equally chaotic. After some confusion, 15 electronics research projects transferred from ORSD to the Cambridge Field Station of the Watson Laboratories. By mid-month, the field station was official and included a programmed staff of 500 civilians and 26 officers. Air Technical Service Command defined the station's mission as not only continuing the ORSD projects, but also the radio and radar R&D role of the National Defense Research Committee (NDRC). Presidential Executive Orders had created both the NDRC (in June 1940) and the OSRD (in June 1941) to "mobilize scientific manpower and facilities, and to coordinate research and development on weapons, devices of warfare, and problems of Military Medicine." The federal government had dissolved the NRDC simultaneously with the OSRD. Following the absorption of selected projects into the workload of the Cambridge Field Station, ARDC would more generally take over the role of NDRC by the early 1950s.[4]

The available World War II Army infrastructure housed the initial physical facilities at Hanscom Field. The airfield had four hangars as of September 1945: "HANG-N-A"[5] for Raytheon, a standard woodframe, Pratt-truss structure (present by August 1942); two identical woodframe, Pratt-truss hangars (of 1943 design); and, a smaller woodframe hangar (present by August 1942 as Hangar No. 1).[6] The Raytheon hangar sat on a taxiway between the northwest-southwest and northeast-southwest runways, while the other three were located together between the northwest-southeast and east-west runways. The two larger hangars on the main apron, described as Hangar A (Building 48) and Hangar B, were a standard Army type (BEMI-AA).[7] East Coast Aviation occupied the nearby small hangar as of 1951, while Raytheon shared its hangar with Atlantic Aviation into the early 1950s. The Radiation Laboratory at MIT occupied Hangar A for radar testing as of late 1944 (with construction the previous spring), also setting up operations in adjacent hilltop structures for a Microwave Early Warning (MEW) test project. The MIT facility, soon known as MEW Hill, featured an AN/CPS-1 relaying radar capable of transmitting to a remote headquarters 60 to 100 miles

distant.[8] The early warning system was primitive, but by the end of World War II was operating between Bedford Field, Arlington, Massachusetts, and the Radiation Laboratory at MIT.[9] In July 1945, after deactivation of the Radiation Laboratory, the MIT facilities at Bedford Field included two rectangular structures for radar transmitting and receiving, and a cluster of five small arched temporary structures (likely Jamesway or Quonset huts often found at radar enclaves).[10] Similar to the Fighter Control Center, MEW Hill was a progenitor for the Aircraft Control & Warning (AC&W) radar network set up for ADC's tiered command post program of ADCCs and Air Defense Direction Centers (ADDCs) of 1949 (see Volume I, Parts III and IV). By 1947, aerial photographs show the hilltop radar facilities as sustaining improvements, with hutments removed.[11] Air Force planners identified all buildings at the airfield by "T" numbers, indicative of temporary construction. The three runways at the airfield were each less than one mile long and were about 150 feet wide. Buildings were scattered irregularly without a gridded street pattern (Plates 59-60).[12]

With the establishment of the Cambridge Field Station of the Watson Laboratories in autumn 1945, facilities for the R&D operation became split between downtown Boston, Bedford Army Air Field, and the Ipswich Antenna Station. Air Technical Service Command located the main laboratories and offices of the station at 224-230 Albany Street in Cambridge in two adjacent buildings formerly occupied the Research Construction Company, an enterprise associated with the OSRD and MIT (Plate 61). In 1946, MIT transferred the Ipswich site to the Cambridge Field Station for the continued testing of radar antennas in development. Ipswich was 35 miles northeast of Boston and featured one laboratory and one dormitory.[13] Ipswich was the first new geographically separate unit (GSU) associated with Hanscom, activated in January and operated for decades as an antenna farm. (The Cambridge Field Station / Center did inherit a GSU in Marblehead, Massachusetts, from World War II. This facility was known as the Marblehead Electronics Research Annex and operated from 1943 to 1957.)[14] At about this same time, the Cambridge Field Station took over MIT's area behind Hangar A at Bedford Field. The MIT facilities at the airfield included "six buildings, all of temporary construction." (Although the MEW Hill buildings were not formally in the allotment from MIT to the Cambridge Field Station, Air Technical Service Command [followed by Air Materiel Command] received occupancy rights immediately.[15]) The airfield provided the aircraft that the station required for radar and electronics test flights.[16] From the beginning, Hanscom Field had operational facilities directly linked to the R&D laboratories located in downtown Boston.

Nearly simultaneous with the Cambridge Field Station's takeover of Hangar A and MEW Hill from MIT, the university erected a new hangar to support its continued role in radar testing at Hanscom.[17] To satisfy its needs, the Instrumentation Laboratory at MIT acquired an excess Army World War II hangar, Type-DH (demountable hangar) –1. The hangar was most commonly found at Army Air Forces training fields, and was used throughout the United States during the war. Designed in 1941, the DH-1 was a "demountable" steel hangar that the Army Air Forces shipped to location for quick, bolted assembly.[18] At Hanscom Field, the DH-1 hangar was initially known as the "MIT Hangar." As of 1949, the hangar occupied a site along a taxiway near the World War II firing-in-butt.[19] As originally designed, the DH-1 hangar featured a center ridge that gave the structure an unusual roofline. MIT augmented its DH-1 hangar by adding an exposed exterior roof-mounted truss of undetermined purpose (Plates 62-63). The source of MIT's DH-1 hangar remains undetermined. It is possible that the university bought the hangar from another Army Air Forces base, disassembled the structure, and shipped it to Hanscom. Equally probable, MIT may have purchased the hangar from Air Materiel Command as a never-assembled, surplus structure. Air Materiel Command (and Air Technical Service Command before it) was responsible for testing and developing prefabricated hangars, nose docks, aircraft engine sheds, and hutments during World War II and throughout the Cold War. Many steel companies in the upper Midwest and Northeast produced prototype structures for test by the command at the Air Proving Ground at Eglin Field in Florida (see Volume II,

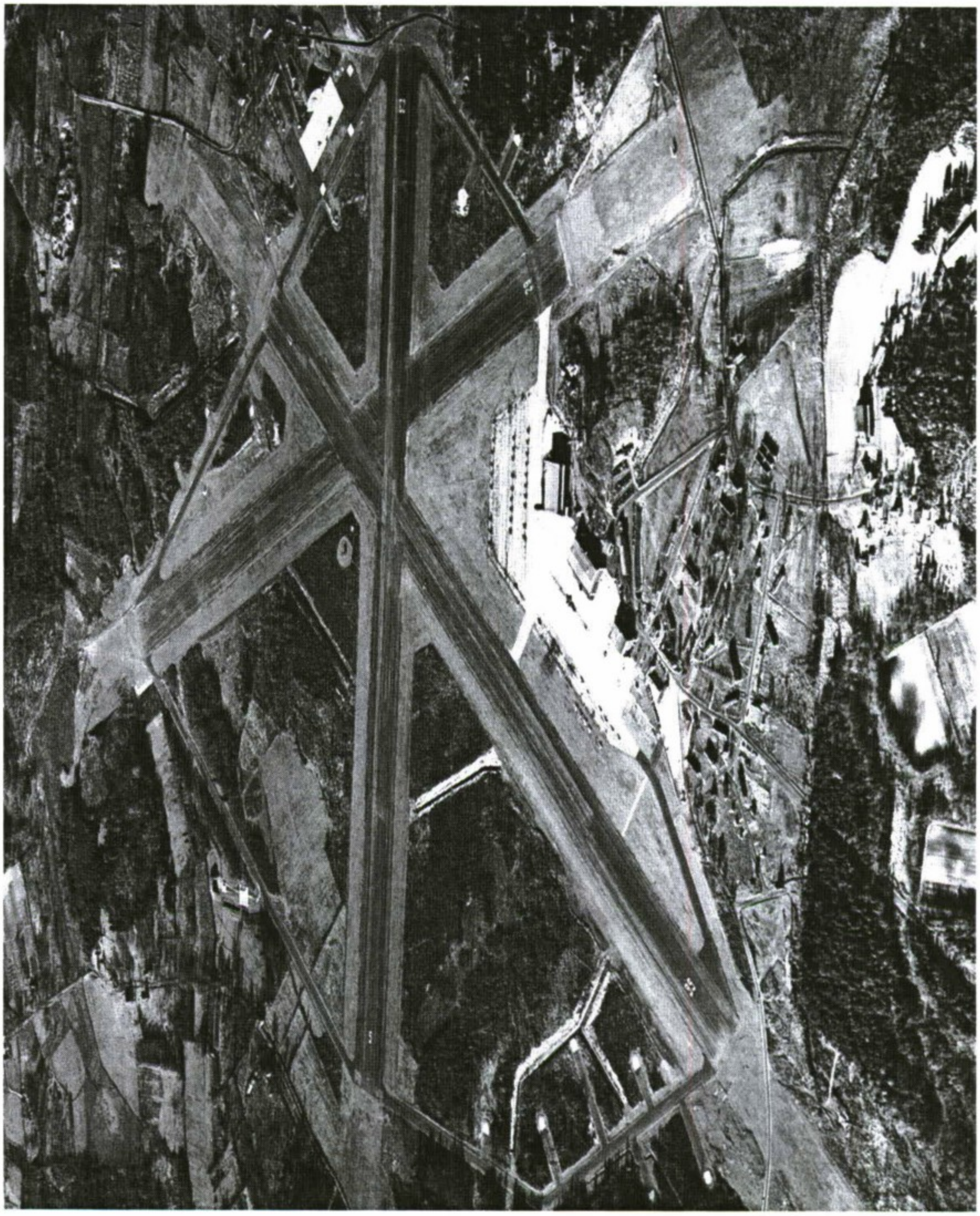

Plate 59: Laurence Lowry. Aerial View of Hanscom Field, 1947. Hangars A and B, center of the photograph, right to left, respectively. (Also, see Plate 71.) MEW Hill, near Hangar A. HANG-N-A (Raytheon), near the upper right edge of the photograph. Hangar B and HANG-N-A are gone today. Hangar A is moved to a second location on the flightline. The MIT hangar is not yet present. Courtesy of the History Office, Hanscom Air Force Base.

Plate 60: **MIT Radiation Laboratory Radar Test Facilities at MEW Hill, Bedford Army Air Field, July 1945. View from a Navy dirigible. Courtesy of the MIT Museum.**

Plate 61: Cambridge Field Station of the Watson Laboratories, 224-230 Albany Street, Boston, late 1940s. Courtesy of the History Office, Hanscom Air Force Base.

Chapter 4). These companies often worked with long-time makers of prefabricated farm buildings, such as Butler Manufacturing. Makers of known World War II demountable hangars included Butler of Kansas City; Luria (with Bethlehem Steel) of New York; the International Detrick and Equipment Company (IDECO) and Armco Drainage and Metal Products Company (a subsidiary of Armco Steel), both of Ohio; and, Stran-Steel of the Great Lakes Steel Corporation of Detroit. The manufacturer of the DH-1 hangar is as yet unresearched. Other examples of the hangar included two pair at the Army Air Forces training bases of Merced Army Air Field (later, Castle Air Force Base) in California and of Williams Field (later, Williams Air Force Base) in Arizona. Two DH-1 hangars also defined the flightline at the Chico Airport in northern California, where the Cambridge Research Center maintained a balloon launch site (Detachment 3) at its Chico Research Site as of May 1963[20] (see Volume I, Part III). MIT constructed a centrifuge adjacent to its DH-1 hangar at Hanscom in 1949.[21]

The earliest Cold War projects of the Antenna, Radar, Relay Systems, Visual Design, RF (Radio Frequency) Components, and Navigation Laboratories of the Cambridge Field Station were of multiple types during late 1945 into mid-1946 and included:

- transmitting / receiving antennas and photoelectric cells installed on V (Vergeltung / vengeance) -2 rockets (with launching at the Army's White Sands Proving Ground in New Mexico);
- an airport taxi control scanner;
- storage tubs for the video removed from radar receivers;
- the MEW radar information relay;
- radar frequency band interference issues;
- vertical, horizontal, and spherical three-dimensional radar display systems; and,
- operational testing of the AN/CPN-18 airport traffic control radar at both Bedford Field and at the All Weather Flying Center maintained by Air Materiel Command at the Clinton County Airport in Wilmington, Ohio[22] (see Volume I, Part II).

The AN/CPN-18 was a project begun at the MIT Radiation Laboratory during World War II.[23] By 1947, Air Materiel Command had successfully transferred 1,500 technical documents and 100,000 drawings from the former MIT Radiation Laboratory to the Cambridge Field Station. During the year too, the command widened its review of possible permanent locations for the Cambridge laboratories. Air Materiel Command decided against a move to Wright Field in Ohio, but continued to look closely at Rome Army Air Field (as of 1948, Griffiss Air Force Base) in upstate New York and at four Massachusetts sites. The latter locations were close to Boston: the Simmons Building at the Watertown Arsenal in Watertown, Fort Devens, South Weymouth Air Base, and Bedford Field. V-2 firings in New Mexico were a major focus of the Cambridge Field Station in 1947. The station ran sky brightness, voltage breakdown, ambient temperature and pressure, and plasma experiments at White Sands using the rocket. The Cambridge Research Station also expanded its in-house capabilities to include a Materials Laboratory. The station housed its new laboratory in temporary space at the Albany Street location.[24]

A second significant emphasis at the station during 1947 was planning toward an early warning radar fence for air defense of the continental United States. John W. Marchetti of the Cambridge Field Station led the efforts. He and four staff members submitted a proposal to the Joint Research and Development Board (JRDB) for a radar fence based on the SCR (Signal Corps Radio) - 270 fixed beam radar that could feed data from remote points into a central defense organization. Marchetti had worked at the Signal Corps Engineering Laboratory at Fort Monmouth, New Jersey, before World War II, assigned by the Army to the Evans Signal Laboratory and the Watson Laboratories in nearby Red Bank during the war. The cluster of electronics equipment laboratories were sited in close proximity in New Jersey. As of August 1945, the Army had made Marchetti commanding officer of the Cambridge Field Station, a position in which he continued after his separation from military service in November 1946.[25] The proposal for a radar fence was the initial effort of the Cambridge Field Station toward its long-term contributions in the development of multiple generations of American air defense networks. Marchetti's submitted abstract to the JRDB called for:

- very-long-range radars with detection capabilities out to 1,000 miles and a minimum target size of one square meter (the ultimate result of which would be the large phased-array radars of the 1963-2000 period);
- long-range radars similar to the SCR-270 / 271;
- short range radars to fill gaps between stations; and,
- a web of air defense control centers into which radars would transmit video information as stored and compressed data via ordinary telephone wire.[26]

Plate 62: MIT Hangar, Virginia Road, Hanscom Field, ca.1947-1948. Centrifuge added later. View of 1972. Courtesy of the History Office, Hanscom Air Force Base.

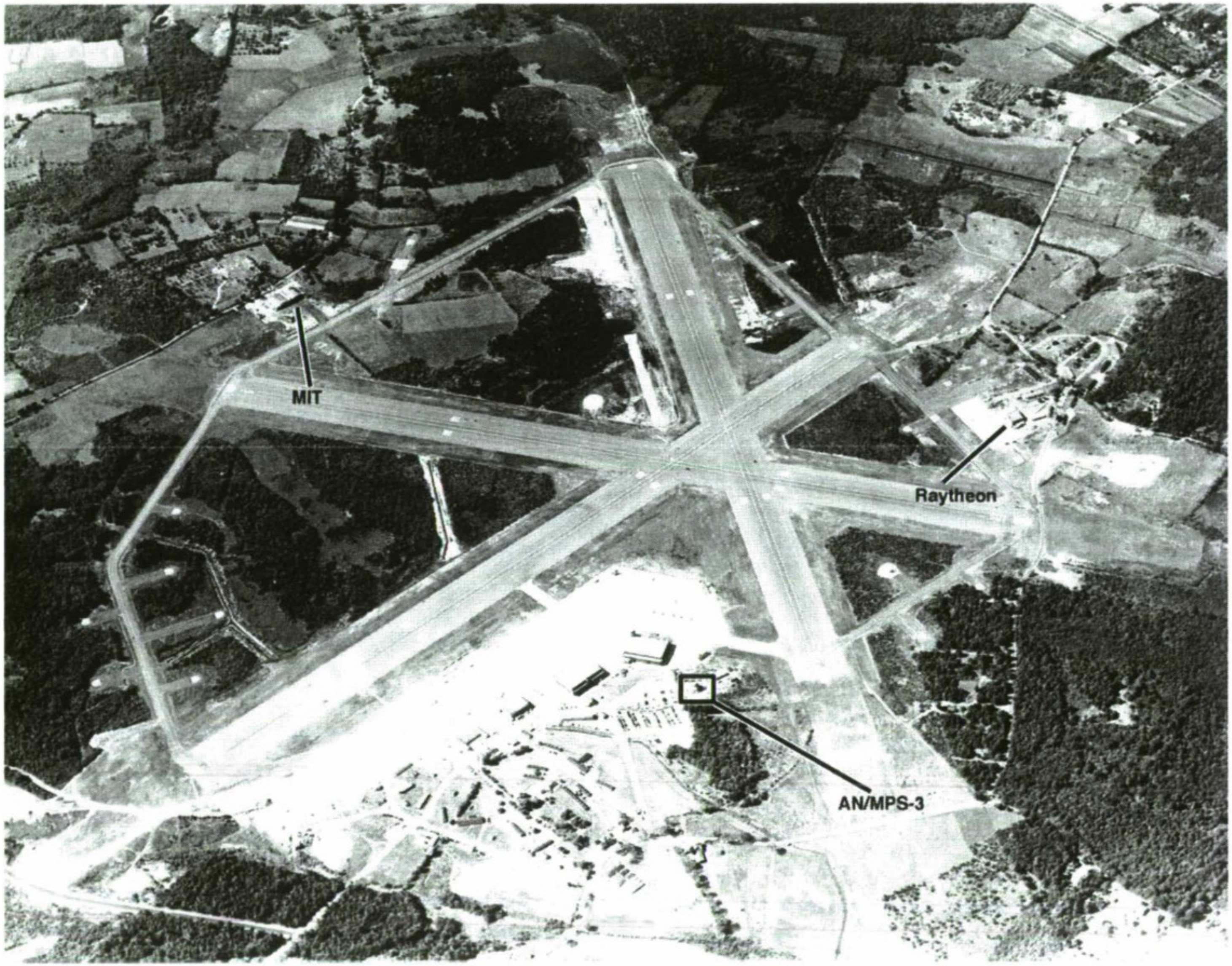

Plate 63: Laurence Lowry. Aerial View of Hanscom Field, 1951. Hangars A and B with MEW Hill, center. Volir radar (AN/MPS-3) is present on large circular mount. Raytheon HANG-N-A at right edge of photograph. MIT hangar at left edge. Annotations added. Courtesy of the History Office, Hanscom Air Force Base.

While the proposal was futuristic, it did define American Cold War air defense. Step by step, ADC (and later, Space Command / Air Force Space Command [AFSPC]) would implement the system laid out by the Cambridge Field Station in 1947. Design and engineering for the first Cold War control centers (the ADCCs and ADDCs of 1948-1949) would be complex, with major contributions by Air Materiel Command at Wright-Patterson, ADC at Mitchel Field in New York; the Watson Laboratories in New Jersey; the Cambridge Field Station (thereafter, Cambridge Research Laboratories / Cambridge Research Center); the RADC at Griffiss; and, the architectural-engineering firm of Holabird, Root & Burgee in Chicago (see Volume I, Parts III and IV, and Volume II, Chapter 12). The SCR-270 (mobile) and SCR-271 (fixed) radars suggested in the proposal were really placeholders. These search radars dated to 1940 and were important "first" radars, but were soon outmoded and replaced by more advanced equipment during the Cold War.[27]

As of mid-1947, the Cambridge Field Station consisted of nine laboratories, including Antenna, Communications, Visual Design, Radar, Mechanical and Electrical, Navigation, RF Components, Relay Systems, and Special Studies. The station continued to be vitally interconnected to MIT, with formal exchange between the Cambridge Field Station and the MIT Research Laboratory of Electronics. V-2 upper atmospheric studies at White Sands Proving Ground grew in complexity and number. Air Materiel Command had plans to fund the Cambridge Field Station at $1,000,000 for facilities and personnel physically located near the proving ground in the vicinity of Alamogordo Army Air Field (Holloman Air Force Base) during fiscal year (FY) 1948. By late 1947, the station had begun the move of its Alamogordo unit to Sacramento Peak in the Sacramento Mountains just east of Alamogordo[28] (see Volume I, Plate 115). Planning for the Blossom V-2 test series was underway in partnership with the Franklin Institute in Boston[29] (see Volume I, Parts III and IV). Air Materiel Command also moved forward in its efforts to acquire the Coast Guard buildings at Fourth Cliff, Massachusetts, for yet another ancillary test site for the station. Fourth Cliff became operational as an electronics research annex in February 1948.[30] (Thirty-four small buildings and 55.67 acres passed from the Harbor Defenses of Boston to Air Materiel Command at Fourth Cliff in March.[31]) With available space a serious problem, the command addressed the possibility of separating individual laboratories within the Cambridge Field Station in new quarters. The Relay Systems Laboratory, for example, already maintained equipment and personnel in the Simmons Building at Watertown Arsenal (four miles from Boston), Fort Devens (36 miles distant), and Groton Hill (five miles from Fort Devens); and, had tentative occupancy rights for an offsite location at Prospect Hill, Hingham, Massachusetts (nine miles from Boston). Several of these locations evolved into subinstallations of the laboratories. GSUs associated with Hanscom during the Cold War were numerous, and often operated for a discrete period of years. Fort Devens supported a geophysics instrumentation annex for the Cambridge Research Center from late 1956 into early 1962. The Prospect Hill Electronics Research Annex activated in December 1947, disposed of by ARDC in mid-1959[32] (Plate 64). The Relay Systems Laboratory continued efforts on MEW relays between Cambridge, Prospect Hill, and Bedford Field, and installed a MEW relay between Cambridge and Watertown as well. Personnel also initiated efforts on the Volscan (volumetric scanning) Relay system (see Plate 66).[33]

During spring 1947, the Cambridge Field Station contracted with Raytheon for an AN/MPS-3 radar, a piece of equipment that featured multilobe height finding techniques and represented the very first innovative detection-and-tracking radar of the Cold War.[34] The Radar Laboratory at the Cambridge Field Station informally designated the AN/MPS-3 as a Volir radar (a volumetric interception radar).[35] By late 1948, the Subpanel on Aircraft Intercept Direction (AID) of the JRDB recommended Volir radars as an important addition to improve aircraft interception across the American military services. The subpanel acknowledged that the radars of World War II (chiefly, the AN/CPS-5 with the AN/CPS-4 height finder and the AN/CPS-6) were only of limited performance against jet aircraft, and of little use for tracking above 25,000 feet. The stated early Cold War

Plate 64: Prospect Hill Electronics Research Annex, Hingham, Massachusetts. GSU for Hanscom Field 1947-1959. Undated view. Courtesy of the History Office, Hanscom Air Force Base.

performance goal of the subpanel was radar tracking of a jet bomber at 30,000 feet 150 miles out from its target, with a pick-up accuracy of 80%. The subpanel recommended that the Air Force and the Navy both pursue "a program on automatic tracking while scanning and [simultaneously engaged] computation." Within the Air Force, Air Materiel Command and the command's contractors were to handle the assignment. Within the Navy, the assignment fell jointly to the Naval Research Laboratory, the Bureau of Ships, the Bureau of Aeronautics, and various contractors. The Subpanel on AID included a chairman from the Department of Electrical Engineering at MIT and 12 members: two civilians (one from Raytheon in Boston and one from General Electric in Syracuse, New York [Electronics Park—see Volume I, Parts II and III]); five from the Air Force (two at Headquarters, two from the Aircraft Radiation Laboratory at Wright-Patterson, and one from the Watson Laboratories in New Jersey); and, five from the Navy (three from Headquarters and two from the Naval Research Laboratory).[36]

The AN/MPS-3 program of the Cambridge Field Station paralleled a similar Navy effort to develop a Volir radar and necessitated finding an appropriate location to test a prototype on behalf of the Air Force. In 1948, the Subpanel on AID noted that the Navy's AN/SPS-2 Volir was in progress (contemporary with work on the Air Force's AN/MSP-3 Volir). The Navy developed the AN/SPS-2 as a shipboard (S) radar (P) for the [aircraft] detection (S) mission, while the AN/MPS-3 was a similar radar for mobile ground use (M).[37] As of late 1947, the Cambridge Field Station requested the continued use of MEW Hill at Hanscom Field for the project, citing the topographical conditions and the proximity to the Albany Street quarters of the station.[38] By 1949, operations at MEW Hill

included the AN/MPS-3 radar and a group of nine World War II buildings (see Plate 63).[39] (Raytheon completed assembly of the AN/MPS-3 as of mid-1948, with delivery to Air Materiel Command late in the year.[40]) Air Force and Raytheon personnel installed the AN/MPS-3 radar in 1949. The feed pattern measurements of the radar were initially "worse than hoped and better than anticipated." As of 1953, ARDC had reoriented, combined, and removed the temporary buildings on MEW Hill. The command reduced nine structures to six, but left the AN/MPS-3 radar intact. In October, the Cambridge Research Center cleared and leveled the site altogether to accommodate an extension of the east-west runway. The center planned to reerect five of the MEW Hill buildings on Katahdin Hill, move the hill's former main structure to Reservoir Hill, and relocate the radar to the Ipswich Antenna Station. At Ipswich, the Cambridge Research Center was concurrently testing the Volscan radar. The Volscan was another early important radar developed by center personnel (see below) (Plates 65-66).[41]

R&D at the Cambridge Field Station during 1948 sustained the station's early Cold War laboratories. The Radar Laboratory monitored an experimental model of a billboard radar for the air defense mission; set up of a test array for a steerable beam radar antenna on the roof of 224 Albany Street; oversaw the installation of an SCR-584 radar on MEW Hill for tracking wind balloons to measure turbulence within storm centers; and, continued efforts on Project Volscan. The Relay Laboratory worked on problems of air defense information transmission, storage, and display, while the Special Studies Laboratory addressed studies for a missile triangulation computer, celestial navigation, a stellar inertial bombing system, and a Volscan tracking-while-scanning computer, among other projects. The Navigation Laboratory moved to the Watertown Arsenal and concentrated on the physics of the upper atmosphere. This laboratory managed the V-2 firings in New Mexico for the field station[42] (see Volume I, Part III). By late 1948, the Cambridge Field Station added a geophysical research group transferred from the Watson Laboratories in New Jersey. Air Materiel Command defined the Cambridge mission as basic and applied electronics and geophysical research. The geophysics projects moved from the Watson Laboratories included varied meteorological research, Arctic propagation studies, contour mapping and thunderstorm experimentation, and atmospheric electricity measurement. Finding appropriate permanent facilities for the Cambridge Field Station was still a dominate issue. By this date, Air Materiel Command planned to reassign the station laboratories to Griffiss Air Force Base in Rome, New York. Not surprisingly, German scientists acquired through Project Paperclip were also becoming a notable presence at Cambridge—totaling eight men (three transferred from Watson Laboratories in Red Bank, New Jersey) (see Volume I, Part III and Volume I, Plate 49). The Cambridge Field Station renamed its Visual Design Laboratory as the Data Utilization Laboratory and physically transferred it to Griffiss. The announcement of a relocation to Rome in February 1948 caused considerable disruption for the station. Many of the highly educated personnel were unwilling to leave Boston for rural upstate New York. Air Materiel Command projected, for example, that the Air Force might lose as many as half the staff of the Radar Laboratory. Air Materiel Command's intentions were to combine the Cambridge Field Station, the Watson Laboratories, and the Electronics Experimental Flight Test Squadron at Olmsted Air Force Base near Harrisburg, Pennsylvania (the Middletown Air Materiel Area [AMA] depot), at Griffiss. The command hoped to achieve the consolidation by mid-1950.[43]

As of 1949, Air Materiel Command had not solved its problems of permanent location for the Cambridge Field Station laboratories, but had postponed a full-scale move to Griffiss until further consideration. The Data Utilization Laboratory remained in Rome, but the laboratories in Boston continued to shift allocated spaces—with the main facilities for the Cambridge Field Station still located on Albany Street. Early in the year, the Radar Laboratory moved out to Bedford Field with the intent that the laboratory would next transfer to Rome. Air Materiel Command again postponed the move due to personnel threats to leave the Air Force.[44] Overall, the Cambridge Field Station laboratories continued radar and geophysics research. The Atmospheric Physics Laboratory (moved

from Watson Laboratories) managed contractors who monitored ongoing atomic bomb tests in the Marshall Islands of the Pacific at the Atomic Proving Ground (begun in 1948) as an expansion of geophysics studies. The Terrestrial Sciences Laboratory also conducted upper atmosphere research and initiated balloon flights to assist information gathering and experimentation (see Volume I, Part III).[45] The Navigation Laboratory evolved into the Upper Air Laboratory. Its personnel continued to increase the magnitude of the program of V-2 launches at White Sands. The Upper Air Laboratory also planned test packages for Aerobee launches at adjacent Holloman Air Force Base. By mid-1949, the Upper Air Laboratory erected the second successful Lyot-type solar coronagraph in the western hemisphere on Sacramento Peak. (The other coronagraph operated at Climax, Colorado.)[46]

Research toward volumetric scanning radars moved forward with the installation of both the Volir (on MEW Hill at Hanscom) and the Volscan (at the Ipswich Antenna Station) as of very late 1949 and early 1950 (see Plates 65-66).[47] Volumetric interception and scanning radar research emphasized multilobe techniques. A secondary objective focused on achieving automatic ground control over a high density of air traffic data. The Volscan was the first radar designed to automatically achieve height, range, and azimuth coordinates on every object scanned. The general air traffic control challenge benefited from the enhanced data base offered through the Volscan experimental radar, as did planning for communications at air defense command posts. The Cambridge Research Laboratories sponsored the Raytheon Volir at Hanscom Field to "provide hemispherical coverage by a medium range radar whereby the position and velocity of a large number of radar targets are rapidly determined with high precision." By 1950, the Volir was explicitly an air defense experimental radar that Air Materiel Command anticipated as appropriate for area defense in situations of high target density. The command's goals for the Volir included a capability to achieve search and three-dimensional target coordinates for 300 targets simultaneously. The Volir radar (AN/MPS-3) was an early step toward the SAGE-compatible radars of the late 1950s. Raytheon, although certainly not the only company that would play a major role in the research, development, testing, and evaluation of air defense radars for ARDC and AFSC, would become a front-runner in such efforts throughout the Cold War and remains so today.[48]

By the end of 1949, the Communications and Relay Laboratory also accelerated research on speech formulation, communications techniques, identification-friend-or-foe (IFF) problem sets, coding, radar data storage, and visual message presentation. These projects applied to the air defense radar and command post network unfolding simultaneously. Laboratory goals for IFF research were to devise a cryptographically secure IFF system to replace existing IFF methodologies by about 1960. The Electro-Mechanical Laboratory designed and built a number of individual units for radars in test, including units for the Volscan and the Billboard radars. The Billboard project featured an electromechanical system for beam steering from a fixed structure. For both new radars, the Cambridge Research Laboratories contracted with four students at the Boston Museum of Art to create isometric drawings of the systems. Upper air research moved forward with additional V-2 launches in the Blossom series at White Sands Proving Ground and the successful launch of Aerobee No. 1 at Holloman (see Volume I, Parts III and IV). Personnel from Cambridge also continued setting up observation equipment for the Upper Air Research Station at Sacramento Peak (also near Holloman).[49] At the turn of 1950, Air Materiel Command organized the R&D programs at Cambridge as two directorates: one in radio physics research and the other in geophysical research. The Radio Physics Research Directorate operated seven laboratories for Cambridge; the Geophysical Research Directorate oversaw five laboratories. Radio Physics concentrated on advancing radar techniques, research on microwave antennas, communications research, and theoretical research. Geophysical Research focused on atmospheric analysis and forecasting, defining the physical characteristics of the atmosphere, and the terrestrial sciences. Cold War military applications of atmospheric forecasting included the control and launching of missiles, chemical and biological warfare, and the testing of atomic weapons. Understanding the physical characteristics of the

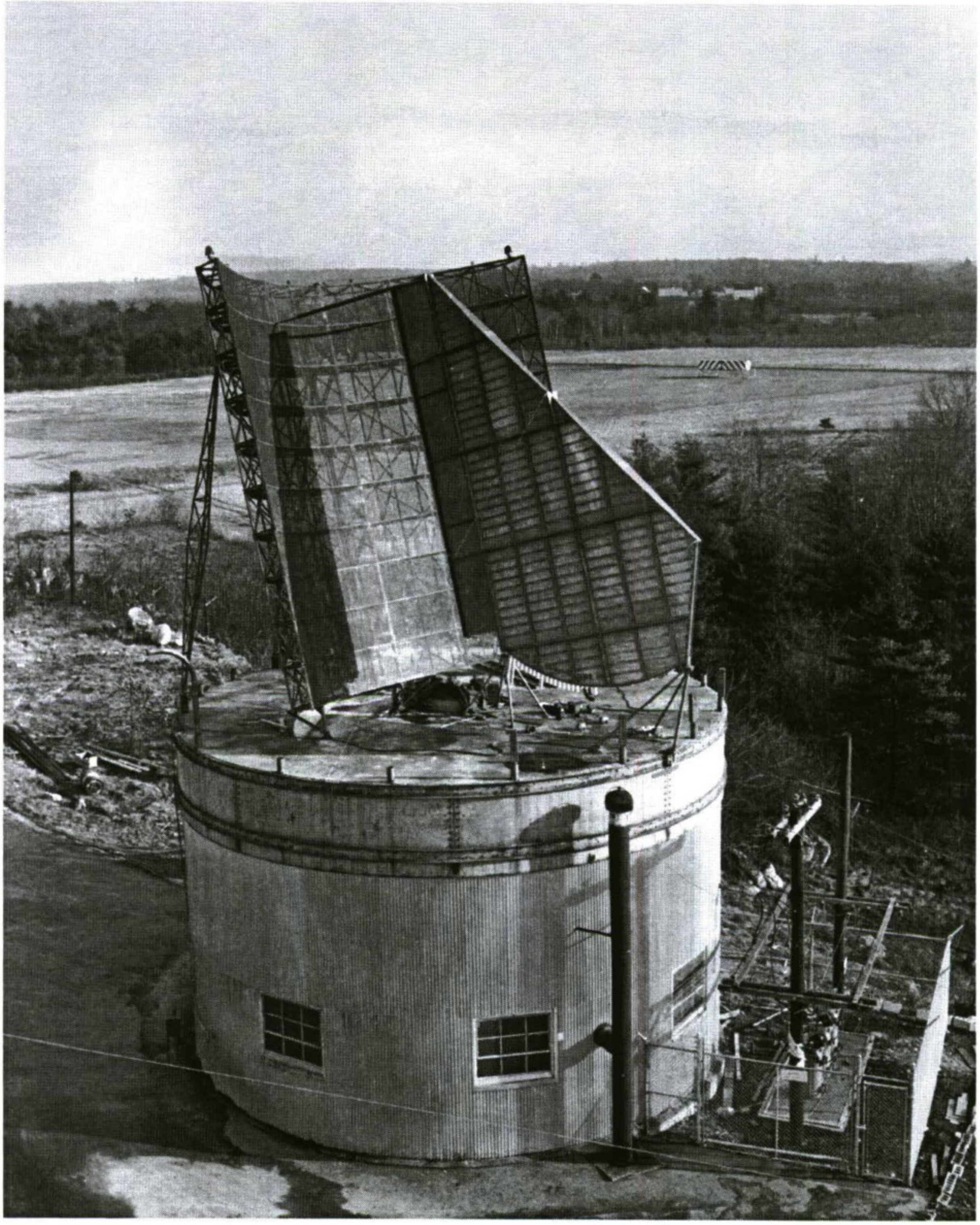

Plate 65: Raytheon. AN/MPS-3 Radar (Volir), MEW Hill, Hanscom Field, 1950. Courtesy of the History Office, Hanscom Air Force Base.

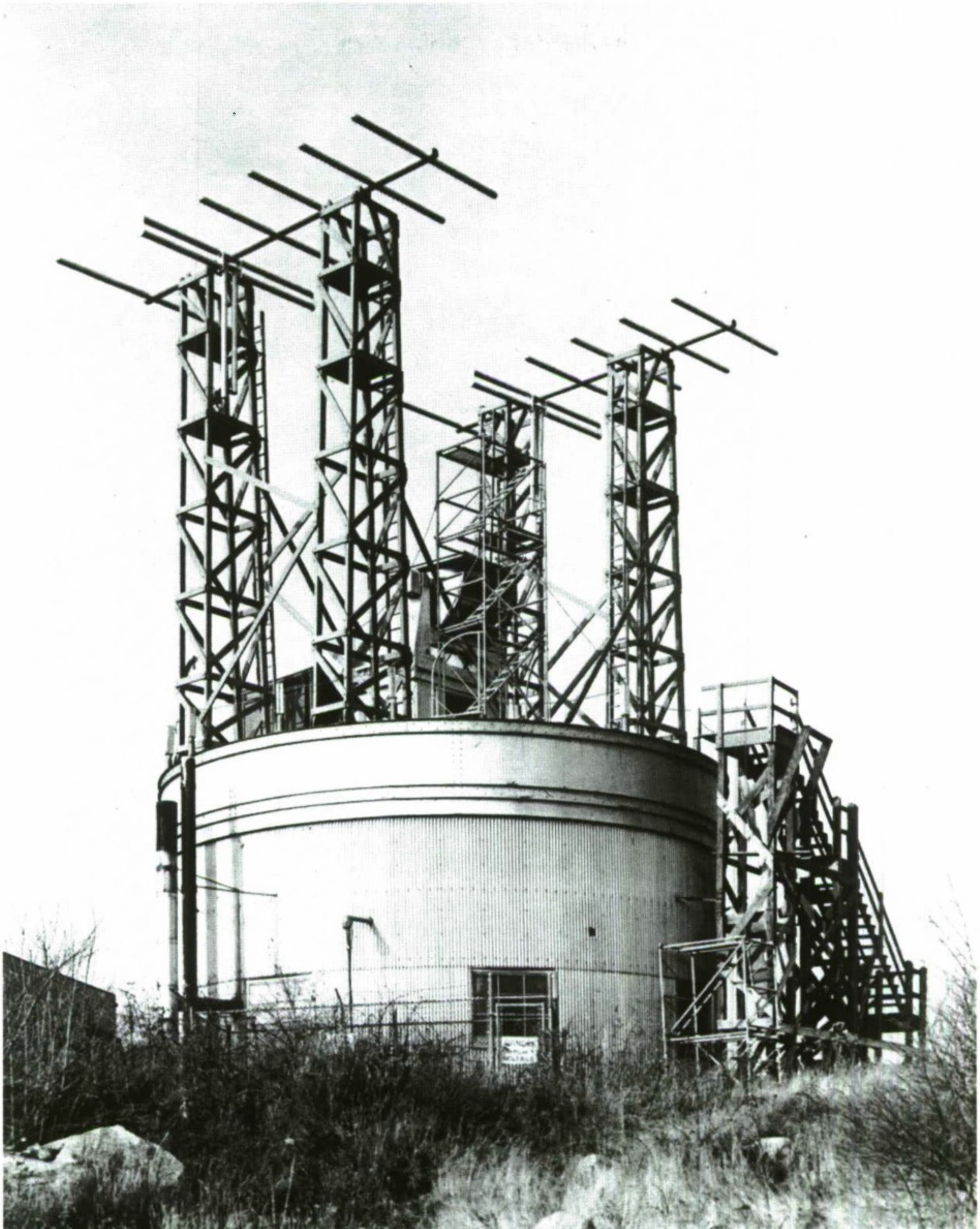

Plate 66: Volscan Radar, Ipswich Antenna Station, near Ipswich, Massachusetts, ca.1953. GSU for Bedford / Hanscom Field, 1946-current. The Cambridge Research Center delivered the Volscan to Ipswich in 1949. (The MIT Radiation Laboratory had operated the Ipswich site during World War II.) Courtesy of the History Office, Hanscom Air Force Base.

atmosphere contributed to the improvement of air defense technologies (better radar detection at long range), of aircraft and missile design, and of techniques for the detection of atomic explosions. Terrestrial science studies concentrated on seismological investigations, blast propagation, and very low frequency sound waves. The laboratories looked at the possibility of using polar ice flows as emergency and routine landing strips, for example, and at wind and temperature information for the upper atmosphere—information required for radiological warfare.[50]

Only as of July 1950 did the Secretary of the Air Force officially approve retention of the Cambridge Research Laboratories in the Boston area. The Air Force had previously announced that the laboratories would move from downtown Boston to Hanscom Field. The onset of the Korean War, coupled with the decision to stay in Boston, nonetheless exacerbated matters and necessitated yet more shifting of temporary quarters. Both the usable space at the Watertown Arsenal and that at Fort Devens became of questionable sustained availability. Air Materiel Command surveyed 15 vacant sites in the vicinity and also evaluated square footage in five Boston buildings (the Lever House, United Distributors, Packard, Cadillac, and U-Divit Buildings). The command acquired 56 acres of additional land at Ipswich on a lease basis and also facilities at Fort Dawes. The latter site became the Fort Dawes Research Annex in June 1950 (disposed of in June 1968).[51] For the Volir project, the Cambridge Research Laboratories added leased sites at Chelmsford, Bedford, and Billerice.[52] Work toward the Air Force air defense network also intensified in 1950, with the Air Defense Systems Engineering Committee (ADSEC) Project established by the Scientific Advisory Board (SAB). ADSEC included MIT physics professor George E. Valley and Cambridge's John Marchetti as members. The SAB charged the committee (more commonly known as the Valley Committee) to design the best possible air defense system. The SAB activated the Air Defense Project as of mid-July.

As of 1950, the laboratories sustained serious air defense projects for the duration of the Cold War. The Cambridge Research Laboratories were:

- to improve and maintain the technical performance of the existing system (as of 1950, the network of ADCCs / ADDCs and AC&W radar stations were actively going in place across the country);
- to devise and recommend new operating procedures; and,
- to analyze current equipment and to begin research toward a second-generation system (which would become SAGE).

The new air defense system (planned for the middle 1950s, but operational at the decade's close) was to feature "low coverage, automatic equipment to speed up data processing, effective integration of data from Civil Aeronautics Authority [later, "Administration"] (CAA), Navy, Army and other installations." The laboratories would contract with Raytheon for X- and L-band continuous wave (CW) radars to provide low coverage and with Computer Research Corporation for special computers to handle data from multiple CW radars. In addition, from 1950 forward, the Cambridge Research Laboratories partially supported Project Whirlwind. An extremely important project, Whirlwind was MIT's study of digital computers for air defense (incorporated into SAGE). In particular, the Air Defense Project included a subtask to install and operate a digital radar relay link from the AN/MPS-3 (Volir) on MEW Hill to the Whirlwind computer at MIT. The Data Utilization Laboratory at Griffiss Air Force Base also received tasking for air defense (see Volume II, Chapter 12). Communications research at the laboratories intensified due to ADSEC responsibilities. MIT was to use the Whirlwind computer to study computer-controlled automatic Ground Control Interception (GCI) challenges. To set up a digital radar relay system in conjunction with the early warning radar at Hanscom, MIT moved laboratory-tested equipment to Hanscom and attached it to the AN/CPS-1 radar on site. The modified AN/CPS-1 then forwarded moving target information to

the Whirlwind at MIT via a telephone line. The crude process enhanced the experimental development of improved computer programs for GCI.[53]

ADSEC recommendations of October 1950 led to MIT's Project Charles, the precursor for what would be called Project Lincoln and the Lincoln Laboratory. Project Charles was underway at MIT as of February 1951, physically set up on the MIT campus in a building acquired for the MIT School of Management. Project Charles members included seven MIT faculty, four faculty from other universities, representatives of industrial and governmental laboratories, and representatives of the American, Canadian, and British Air Force, Army, and Navy. John Marchetti served as the Air Force civilian member and represented the Cambridge Research Laboratories. F. Wheeler Loomis of the University of Illinois headed Project Charles for MIT while on leave from his university. In 1950, Loomis had invented random-access core memory (RAM) to replace the existing limited technology of cathode-ray-tube (CRT) storage—that is, digital versus analog technology for computers. RAM "doubled the operating speed, quadrupled the input data rate, increased the mean time to failure from two hours to two weeks, and reduced the maintenance time from four hours a day to two hours a week."[54]

In early 1951, Hanscom Field became officially known as Laurence G. Hanscom Field, returning to the mid-1941 civilian name for the facility.[55] The airfield had chiefly functioned as a research test site following World War II. Throughout the late 1940s, the Cambridge Field Station (Research Laboratories) had continuously used available Army buildings for both radio physics and geophysics research. MIT sustained access to the airfield for nuclear and weather research, instrumentation fire control, and guided missile research for both Air Force and Navy contracts. Raytheon and Bendix also had an active presence at the former Army base. Raytheon conducted radar research and electronics testing, while Bendix operated a radio experimental laboratory on site. By 1951, Boston University also ran an optical research laboratory at Hanscom Field to carry out aerial camera research for the Air Force.[56] As the Air Defense Project unfolded, activities at Hanscom Field increased even further, as did connections to MIT. Dr. Valley's recommendation for an air defense laboratory at MIT led to Project Lincoln by late 1951 (as a follow-on from Project Charles). The Air Force funded Project Lincoln as a joint endeavor for itself, the Army, and the Navy. Valley, a physicist, had envisioned taking data from many small radars and correlating it via computer in a task that required the conversion of analog radar signals into digital radar data. Both radars and computers were analog up to this point. To achieve Valley's vision, systems engineers needed to change selected components in radars and computers to a digital format to allow many thousand times more arithmetic calculations per second—a prerequisite for complex air defense of the Cold War era.[57] At the outset of 1951 also, the Cambridge Research Laboratories stepped forward, working with MIT, to informally suggest planning and design for the much-needed new physical infrastructure at Hanscom Field.

As early as June 1948, Robert M. Barrett, Chief of the Airborne Antenna Research Branch of the Antenna Laboratory, had suggested that the Cambridge Field Station approach a school of architecture in Boston to design model science laboratories as a baseline for decision-making by Air Materiel Command. Mr. Barrett immediately involved the Graduate School of Architecture at MIT. He provided the school with technical specifications that he developed on his own time. Twelve students submitted projects through a collaborative effort with professors Laurence B. Anderson and Ralph Rapson. The design process with MIT was elaborate, and Air Materiel Command reviewed submissions into 1949. By 1950, Wright-Patterson used one of the MIT designs, coupled with Mr. Barrett's technical specifications, to prepare a budget for the design of the laboratory complex. After the Air Force rejected Griffiss as the permanent location for the Cambridge Research Laboratories, the design process accelerated. As of this year, Air Materiel Command intended to build a complex of state-of-the-art laboratories at Hanscom Field and in June the command

redesignated the Cambridge Field Station as the Cambridge Research Laboratories. Mr. Barrett and the Cambridge Research Laboratories (Center) remained intensely involved in the process as it unfolded during 1951. On behalf of the laboratories, Mr. Barrett prepared a detailed analysis of recently constructed science laboratories in both the university and industrial communities. ARDC (following on from Air Materiel Command) selected the prestigious Boston firm of Coolidge, Shepley, Bulfinch & Abbott for the Cambridge Research Laboratories project. By late in the year, the command chose a second well-known Boston firm, Cram & Ferguson, for design of the Air Defense Laboratory to be operated by MIT (for Project Lincoln). The entire process continued into the middle 1950s and was an excellent example of a tightly controlled effort to create a collegiate cluster of modern laboratories (see Volume I, Part III and Volume I, Plates 63-69). By autumn 1952, construction was underway for the Lincoln Laboratory, with design efforts not finalized for the Cambridge Research Center cluster until mid-decade (Plate 67).

While planning, design, and construction for permanent facilities went forward for Hanscom Field during the early and middle 1950s, the Cambridge Research Center continued operations from downtown Boston. The center maintained a balloon-launch detachment at Holloman Air Force Base, along with launch sites elsewhere, in a continued complex program tied to basic upper-air research and atomic-biological-chemical (ABC) weapons development. As of mid-1951, the Cambridge Research Center initiated Moby Dick to observe wind fields at altitudes of 50,000 to 100,000 feet.

Plate 67: Cram & Ferguson. MIT Lincoln Laboratory under construction at Hanscom Field, ca.1953. Buildings 1302 A (background left), 1302 B (middleground center), and 1302 D (right). The Experimental Control Center ("ADCC") for the 6520th AC&W Squadron (Experimental) [Building 1301] is visible between Buildings 1302B and 1302D in the deep middleground. Annotation added. Courtesy of the History Office, Hanscom Air Force Base.

Cambridge's primary Moby Dick launch and launch training location was at Holloman, but the laboratories also set up launch sites in California and Oregon. As of mid-1953, the Cambridge Research Center also took over a second major balloon endeavor, Project Gopher. Both Moby Dick and Gopher were tied to biological weapons R&D (see Volume I, Part III). Planning for an upper air observatory on Sacramento Peak also advanced. Sacramento Peak offered atmospheric conditions that fostered "exceptional astronomical 'seeing'...one of the best known locations in the United States for operation of a coronagraph."[58] The peak was the preferred location for the Cambridge Research Center to measure solar activity. By mid-1951, Public Land Order No. 656 authorized the transfer of 54,294 acres of the Lincoln National Forest in New Mexico to the Department of the Air Force for the Cambridge Upper Air Research Observatory on Sacramento Peak. The Cambridge Research Center anticipated placing 19 families and 16 single permanent residents at the location[59] (see Volume I, Part IV and Volume I, Plate 115).

As construction for MIT's Lincoln Laboratory at Hanscom Field began in late 1951, ADC was also completing its network of command posts (ADCCs and ADDCs) across the continental United States. Part of the charge given to the Cambridge Research Center for air defense R&D included improvement of existing systems and work toward what would become SAGE—both also recommendations of Project Charles. The priority of air defense, as well as a need for speed, quite predictably led to a temporary project at Hanscom while the Air Force completed its longer-term facilities on base. The Cambridge Research Center and MIT jointly set up a smaller Data Link Project at Hanscom Field to support Project Lincoln. MIT outfitted a B (bomber) -25 with a Sperry zero reader. The device allowed a pilot to maneuver the World War II aircraft in two dimensions under ground control. The pilot could also transmit azimuth commands to a ground station. The project's test flights at Hanscom Field supported the first data link of this type. MIT also modified a second World War II bomber, a B-26. University personnel installed very high frequency (VHF) equipment to create a flying instrumentation laboratory with an autopilot capability. MIT set up a temporary station in Hangar A for testing its data link equipment. The miniature laboratory in the hangar was a direct continuance of MIT's use of the building from 1945. MIT also added a plan position indicator (PPI) for the Volir radar on MEW Hill to generate control information for test flights.

The MIT-Cambridge Research Center Data Link Project of late 1951 initiated a type of testing required for making the ADC command posts as nearly automatic as possible, with an emphasis on the role of a high-speed digital computer.

> On the ground the MIT Whirlwind Computer could calculate a collision course for either plane [the MIT-modified B-25 or B-26]...At the Barta Building in Cambridge [on the MIT campus] a coder stored the time-parallel command long enough to convert it to time-serial form. Following a 12-millisecond starting pulse, the information was transmitted over a high-quality phone line to AFCRC [Air Force Cambridge Research Center]. At AFCRC a special modulator keyed a BC-640 VHF transmitter on and off in response to the message, and the signal was radiated from an omni-directional antenna having 2.7 decibels (db) of vertical gain.
>
> Alternatively, a test command could be generated at Bedford [Hanscom] and set up on a shaft-position-to-digital coding wheel. The resulting time-parallel message was sent to AFCRC in Cambridge over a low-quality phone line by means of very slow pulses generated by a 'slow-scan relay.' At Cambridge [the 224-230

> Albany Street buildings] the information was again stored in time-parallel form, and a second coder, similar to the one at the Barta Building, processed the pulses for transmission on the air.
>
> In either the B-25 or the B-26, the message could be picked up on an ARC-3 receiver modified by the addition of a low-noise front end. The signal was fed to a special filter known as a 'recognizer,' whose duty it was to decide first, on the basis of the starting pulse, whether or not a message had been sent and second, what the digits were. This unit then re-created the message in noise-free form and passed it on to a decoder, where it was converted to time-parallel representation. Next, the digits were stored by means of relays in a transducer, and finally a digit-to-shaft-position decoder, supplied by Collins, translated the message to a form suitable for feeding either the zero reader in the B-25 or the autopilot in the B-26. In the former case, the pilot acted as the coupler to the flight controls, while in the latter case no human intervention was necessary.[60]

The Data Link Project also addressed a sustained look at coded communications. The intent was to transmit information protected against noise and jamming, but allowing authentification and a process for IFF (Plate 68).[61]

In order to evaluate and improve the air defense command and control network of the early 1950s, the Cambridge Research Center and MIT's Lincoln Laboratory had to establish an experimental version of ADC's command post, radar station, and FIS operations. The setup during 1952-1954, in particular, was transitional. Griffiss Air Force Base provided the 6531st Flight Test Squadron to support radar and communications testing by MIT at Hanscom. The 6520th Test Support Wing soon replaced the 6531st, but still used 16 fighter aircraft loaned by the New York installation. As of mid-1954, construction was underway for a standard FIS alert complex at Hanscom Field to augment data link testing for SAGE. The 49th FIS, flying F-86Ls, functioned both for SAGE electronics testing and ADC alert. The infrastructure included a four-pocket standard Strobel & Salzman alert hangar, four standard Strobel & Salzman readiness maintenance hangars, a readiness crew dormitory, and a Unit A rocket storage, checkout and assembly building (see below). The alert complex was streamlined in its operations units and expanded in the number of maintenance hangars, indicative of a mission concentrated on testing rather than primary alert (see Volume I, Part IV). ADC maintained a double FIS alert squadron at Otis Air Force Base on Cape Cod to carry out the primary air defense duties for the Boston area. (ADC also erected an eight-pocket Butler alert hangar at Griffiss.) The command also placed a single FIS on alert at Grenier Air Force Base in Manchester, New Hampshire, to the near north of the Boston area, and at Suffolk Air Force Base on Long Island, to the south (both with a four-pocket Butler alert hangar). The Boston metropolitan area was an important one for an air defense posture. ADC's placement of Butler alert facilities in concentrated regional proximity is indicative of a significant air defense mission for the area as of 1951 (see Volume I, Part IV).[62]

A second component of Cambridge Research Center and Lincoln Laboratory testing for ADC's command and control network was more complicated—that of working with the existing ADCC / ADDC system while planning toward SAGE. Neither MIT nor the Cambridge Research Center built a command post from the Holabird, Root & Burgee designs for the Type 2 (ADDC) or Type 4 (ADCC) Operations Buildings of 1949, although the Air Force did construct exactly such a test and evaluation facility in 1952-1953 at Eglin Air Force Base in Florida (the Air Force Operational Test Center [AFOTC]—preceded by a temporary Air Operations Center) (see Volume II, Chapter 4). Nonetheless, testing required a representative command post near Hanscom. To facilitate

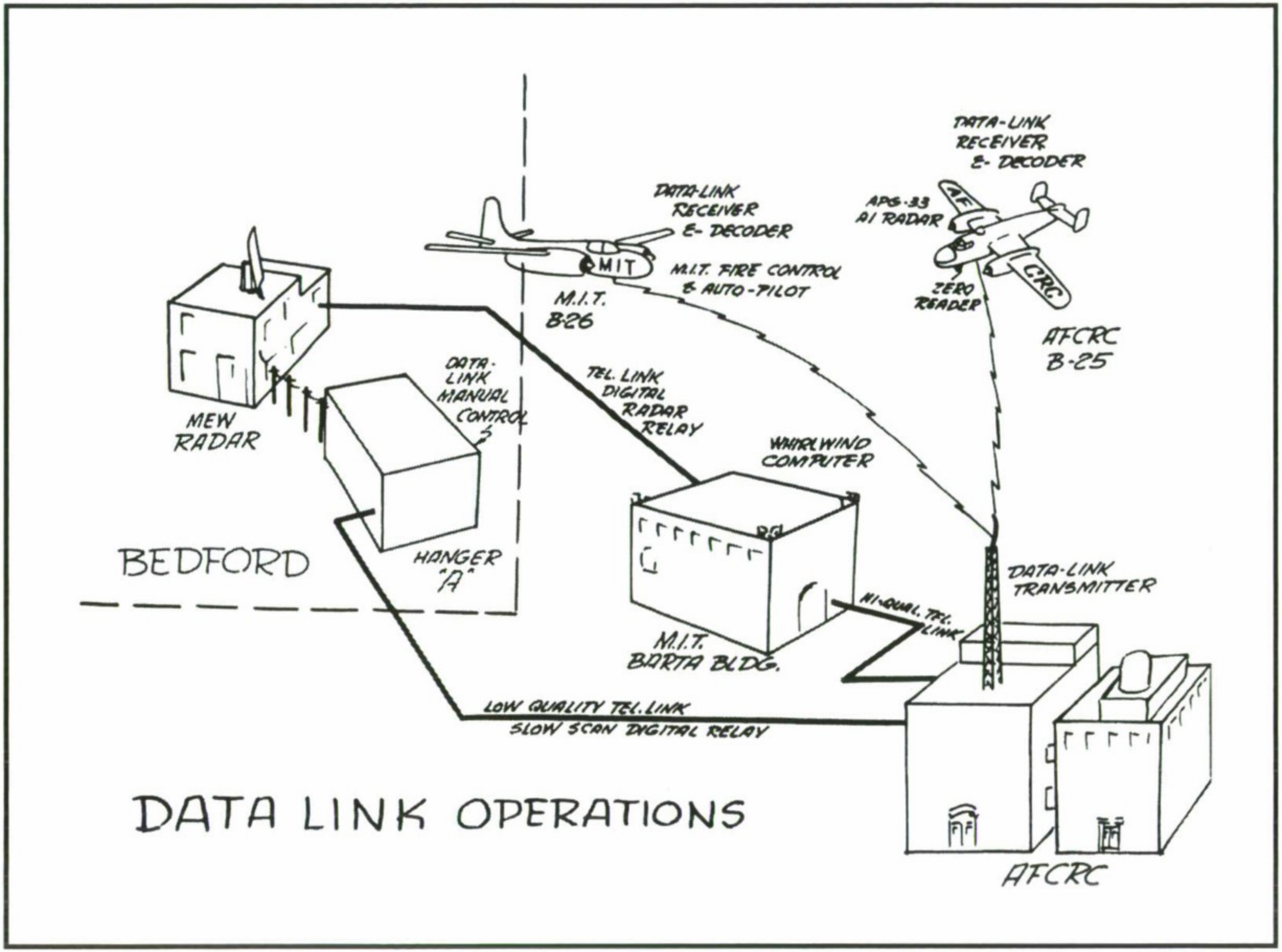

Plate 68: **MIT and the Cambridge Research Center, Data Link Project at Hanscom Field, late 1951. In *History of the Air Force Cambridge Research Center 1 July – 31 December 1951*, volume 15, part 1.**

this need, the Air Force initially activated an AC&W Squadron (Experimental) at the MIT Field Station on Katahdin Hill by early 1952. The Air Force did not formally number the squadron as the 6520th until October.[63] The MIT Field Station neighbored the Lincoln Laboratory to the south. The physical infrastructure is assumed to have been a temporary or prefabricated structure, paralleling the use of hutments on MEW Hill at the end of World War II. As of 1954, Katahdin Hill included four small World War II woodframe buildings, a tower, and a meteorology unit.[64] The Air Force had moved five of these structures from MEW Hill the year before, which suggests that only the 6520th AC&W Squadron (Experimental) structure existed on site during 1951-1952. As of April 1952, the squadron moved into the first of the buildings completed for the Lincoln Laboratory (Building 1301)[65] (see Plate 67, and Volume I, Plates 65 and 69). Building 1301 then functioned as the ADCC for pertinent electronics testing undertaken by the Cambridge Research Center and Lincoln Laboratory. Named the Experimental Control Center in 1952, Building 1301 became a surrogate Type 4 Operations Building during its earliest months. Building 1301 was a stand-alone, one-story structure constructed of reinforced concrete with concrete block walls. The building was very small (763 square feet), but served its purpose. To make the mockup of the tiered first-generation air defense command post system complete, the Cambridge Research Center and Lincoln Laboratory also needed an ADDC. To fill this need, the laboratories turned to an existing facility in an Type 2 Operations Building located at North Truro.

At the North Truro site, the 6521st AC&W Squadron (Experimental) replaced the existing 762nd AC&W Squadron to support testing at Hanscom Field. ADC first assigned a compliment of men within the 762nd AC&W Squadron to Project Lincoln in December 1951 as a transitional measure. In March 1952, ADC reassigned 27 of the airmen from that squadron to the newly organized 6521st AC&W Squadron (Experimental) at Hanscom. The Air Force had organized the 6521st AC&W Squadron (Experimental) to assist in "the development of experimental techniques in the operation of aircraft control and warning systems and to operate an Air Defense Direction Center [ADDC] in support of Project LINCOLN." Hanscom Field supported both the 6520th AC&W Squadron (Experimental) and the 6521st AC&W Squadron (Experimental)—the former through mid-1957 and the latter through mid-1962. Timing of the incorporation of the North Truro ADDC into Project Lincoln is of note, as construction of the standard Holabird, Root & Burgee Type 2 Operations Building on site was nearing completion. Access to the building allowed the Cambridge Research Center and the Lincoln Laboratory to test air defense equipment and data links in an actual ADC command post, rather than in a surrogate environment. North Truro's ADDC would have an especially long Cold War role. Following the end of North Truro's assignment to ARDC / AFSC in July 1962, the facility continued to operate as an air defense command post as part of the BUIC II and III program into the early 1980s (see Volume I, Part IV). The Air Force assigned North Truro directly to the Cambridge Research Center, rather than to ADC during the 1952-1962 period. About 55 airmen staffed the ADDC at North Truro. The Cambridge Research Center dispersed another 100 men to radar sites incorporated into the experimental Cape Cod Net for Project Lincoln.[66] MIT described Project Lincoln's work with the existing ADCC / ADDC network as the "Quick Fix System." MIT planned Quick Fix to improve command post electronics and communications, pending development of a much more automated system based on advances achieved through the Whirlwind computer (SAGE). Quick Fix depended on new equipment that allowed personnel in ADDCs to interpret existing radar data more accurately and more rapidly. If AC&W squadrons could forward better information from the ADDCs to the regional ADCCs, then the men stationed in the ADCCs could deploy weapons systems such as FIS alert squadrons more quickly.

MIT analyzed ADDC operations as requiring men to perform too many actions, a situation that led to errors and delays. Quick Fix segregated tasks and assigned as many tasks as possible to machines. Whereas radar data under the existing air defense command and control system came into a single filter, plot, identity, and operations room (with horizontal plotting boards and men stationed at a

wrap-around tiered dais), Quick Fix placed detection and plotting in one room, identification and filtering in another, and control or operations in yet a third. ADC's methods of 1949-1952 featured men reading raw data to hand plotters, who then marked a display board with x and y coordinates. Another individual assessed the plotted tracks, with flight data plans on a second board. The senior controller evaluated the situation and assigned subordinate controllers to specific intercepts. The information then passed from ADDCs to ADCCs by telephone, where men recreated the scenario again on horizontal plotting boards by hand. The key problem with the methodology was its openness to confusion and mistakes when there were many tracked targets. The system was a direct descendent of that created by the RAF during World War II, and was also that used in the Fighter Control, Information, and Filter Centers established in the eastern and western continental United States late in the war.

Quick Fix redesigned the interior of the ADDC and reorganized its operations.

> [A] Polaroid 'A' camera was used to photograph a PPI 'scope and project the picture onto a horizontal plotting board [eliminating reading information out loud and hand plotting]. Superimposing several successive pictures made it possible to identify tracks quickly. Such tracks were marked by hand and identified and then re-marked with special markers showing whether they were friends or enemies. The resulting display was then re-photographed and the picture projected on a vertical display board in the operations room where the Senior Controller could assign targets to duty controllers, each of whom had his own PPI 'scope to work from. Forward telling (to another station [ADDC] or higher echelon control center [ADCC]) was done by a facsimile system which reproduced the operations room picture. Provision was made for the display of other data from outside sources through the use of a teleregister tote board.[67]

Quick Fix, however, was somewhat cumbersome. The program depended on machines that were not automated and subject to breakdown (Plate 69). The Air Force felt that Quick Fix was too complex and offered only incremental improvements. The Lincoln Laboratory next streamlined the original Quick Fix by reducing costs and simplifying equipment. The improved Quick Fix relied on a vidicon camera "to transmit processed radar data over telephone lines and to reproduce it on the vertical boards at the Combat Center by a means known as 'similitude.' However, this development like Quick Fix itself was to come to naught." Air Proving Ground Command tried the improved Quick Fix in its Air Operations Center at Eglin and found it to be undesirable (see Volume II, Chapter 4). By mid-1953, the Air Force elected not to build either Quick Fix into existing ADDCs (with the setups at North Truro and Eglin the only examples). ADC did give MIT permission to try yet a third idea, which the university named Phoenix. For Phoenix, a photocell scanning device transmitted target locations on the PPI display via regular telephone lines to the ADDC and the ADCC (rather than relying on human interpretation of the information and voice transmittal). Hand plotters continued the process once the information was at the control centers. Phoenix eliminated one human stage, added accuracy and speed, and required no rearrangement of existing ADDC interiors.[68] Although ADC did not adapt Quick Fix or Phoenix at any of its ADDCs of the 1952-1956 years, the command did add a series of continually improved plotting boards at the ADCC level. For example, at Tinker Air Force Base in Oklahoma the ADCC for the region converted to a redesigned vertical plotting board in late 1955 (see Volume I, Part IV). Most of the effort toward upgrading plotting boards for air defense situation rooms would become a mission of the RADC as of about the middle 1950s (see Volume II, Chapter 12).

Plate 69: MIT (Lincoln Laboratory) and the Cambridge Research Center, the Quick Fix Filter Room in the ADDC at North Truro, Massachusetts, 1952. In *History of the Air Force Cambridge Research Center 1 July – 31 December 1952*, volume 17, part 1.

The Lincoln Laboratory followed Quick Fix with its Lincoln Transition System. For the Lincoln Transition System, MIT advised automating the existing ADCC / ADDC network as much as possible. The Lincoln Transition System was actually the earliest name for developmental SAGE, reliant on then-current radars. Once again the goal was reduced error and improved speed of information access, focused on computer capabilities.

> More equipment could be added later as needed with a minimum of effort. Its installation would not endanger the completion schedule of the 'Future System' [SAGE] since all the elements of 'Transition' would be used later anyhow and would have to be installed and put to work. Capacity could be varied simply by varying the amount of equipment hooked into the system. Since the system was built about a general purpose computer, changes could be affected simply by changing the program control (either punched cards or tape) of the computer. ...By doing a large amount of work per vacuum tube it reduces system complexity to a minimum.[69]

The Lincoln Transition System required testing and continuous improvement through the creation of an experimental air defense sector that overlapped with Quick Fix. To develop the Lincoln Transmission System, the Cambridge Research Center, MIT, and RAND collaborated on the Cape Cod Muldar Net, soon to be known as the Cape Cod System, and as of mid-decade, the Experimental SAGE Sector. The Douglas Aircraft aeronautical think tank RAND (Research and Development), with a primary location in Santa Monica (greater Los Angeles), dated to just after World War II (see Volume I, Part III). By 1948, RAND was an independent organization functioning for the Air Force in a nonprofit capacity, and one which addressed a wide spectrum of R&D issues. RAND devised and named the MULDAR air defense scheme for ADSEC (the Valley Committee) by either late 1951 or early 1952. MULDAR disappears quickly as a specific program name, and the meaning of its acronym is undiscovered. RAND noted that MULDAR was different from any then-existing program for managing air defense, in its organization and its instrumentation. MULDAR was a

> land-based operation...[that]...envisaged the utilization of a great many radar sets and digital computers to achieve very large traffic handling capacity and flexibility of operation for perhaps 1,000 targets. ...MULDAR was conceived as a system capable of fully automatic operation, including all phases of evaluation and weapon assignment.[70]

RAND, similar to the Lincoln Laboratory and the Cambridge Research Center, sustained a direct role in the management of Experimental SAGE at Hanscom Field. As of June 1955, Headquarters ADC designated and organized the 4620th Air Defense Wing (Experimental SAGE) at Hanscom. The wing was affiliated with the Lincoln Laboratory. (The same month, the Cambridge Research Center officially moved from its operating location on Albany Street in Boston, to Hanscom Field.[71]) RAND erected its own laboratory cluster of buildings for its air defense mission on base. RAND's operations at Hanscom were temporary, tied to Experimental SAGE. To accommodate those constraints, RAND set up eight Butler buildings, each an elongated single-story wing of offices, adjacent to the Lincoln Laboratory (see Volume I, Plate 70). ADC organized the 4620th Air Defense Wing (Experimental SAGE) in advance of the office space, with the Butler buildings dating to August 1956.[72] The RAND Butler complex was still standing as of 1963, although the mission of the 4620th Air Defense Wing (Experimental SAGE) ended in June 1958.[73] (These buildings are no longer extant today.) ADC planned testing for SAGE in four phases: at Hanscom; at Stewart Air Force Base in southern New York; at Hancock Field in Syracuse, New York; and, at a flexible final site for an overall systems check[74] (see below).

MIT recommended specific components for the complete Lincoln Transition System, including early warning radar (distinct from the long-range radars earlier suggested for a radar fence ringing American borders), picket-ship radars, and radar-equipped aircraft flying 400 miles apart. Each of these devices would feed into ground communications stations linked to air defense command posts. The Lincoln Transition System also evaluated several possibilities for associated air defense weapons. MIT personnel first suggested "Porcupine" and "Quill" for the system. Porcupine fired 100 rockets at a target as an enemy breached air defenses, while Quill launched clusters of rockets—foreshadowing the multiple independently targetable reentry vehicles (MIRVs) of the much-later Minuteman III and Peacekeeper intercontinental ballistic missiles (ICBMs).[75] To develop the Lincoln Transition System, MIT and the Cambridge Research Center relied upon tests run using the FIS and Experimental Control Center set up at Hanscom, the ADDC at North Truro, and affiliated radar and communication sites within the Cape Cod System. By late 1952, the Lincoln Laboratory at Hanscom anticipated replacing the Experimental Control Center established in Building 1301 with a new center built around the Whirlwind computer. The second experimental center would evolve as the XD (experimental development [digital]) -1 Building (Building 1302F) of 1955, better known as the Experimental SAGE Direction Center.

While the Cambridge Research Center worked with MIT on Project Lincoln during 1952 and 1953, the RADC at Griffiss issued a parallel air defense contract with the University of Michigan's Aeronautical Research Center at Willow Run. The University of Michigan adapted the Comprehensive Display System (CDS) of the British Royal Navy to American radars, renaming it the Air Defense Integrated System (ADIS). The RADC's contract with the University of Michigan stipulated that their work would include

> the study of techniques leading to the design of components for the data processing system, studies covering digital and analogue techniques applicable to target tracking and data storage, the problems relating to the weapons assignment section and switching facilities at both the Air Defense Direction Center [ADDC] and Air Defense Control Center [ADCC] level.[76]

In 1951, the RADC also built its own experimental Operations Room at Griffiss, in a prefabricated steel Butler building (see Volume II, Chapter 12). At about the same time, the ADCC for the 32nd Air Division (Defense) moved from a previously completed Type 4 Operations Building at Stewart Air Force Base in southern New York, to Hancock Field in Syracuse, in proximity to Griffiss and the work of the RADC. [The ADCC at Stewart then became the permanent command post for the 26th Air Division (Defense), replacing the World War II Fighter Control Center at Roslyn on Long Island.]

ARDC, through its Cambridge Research Center in Boston and the RADC at Griffiss, had issued competitive contracts to two major universities to study the air defense problem set with specific ADDCs (North Truro, Massachusetts) and ADCCs (Willow Run, Michigan, and Syracuse, New York) important to early experimental efforts. The Air Force evaluated the two plans for computerized command and control, the Lincoln Transmission System and ADIS, into mid-1953. MIT adapted the just completed ADDC at North Truro for its experimental command post, while the University of Michigan appears to have relied on a similar solution at Willow Run. The ADCC for the 30th Air Division (Defense) (a Type 4 Operations Building, rather than the Type 2 Operations Building of the ADDC) became operational at the outset of 1952 at the Willow Run airport southwest of Detroit (see Volume I, Part IV). (Not researched here is the possibility of any special reconfigurations of the interior of the Willow Run ADCC for the ADIS project, paralleling MIT's changes to the North Truro ADDC for Quick Fix.) In May 1953, ARDC discontinued the University of Michigan study and turned all efforts over to MIT. At this point, the command gave the go-ahead to MIT to create the Cape Cod System as a military test environment.[77] As of 1956, ADC would erect paired SAGE Combat and Direction Centers (one of three of the double complexes for the nation) at Hancock Field in New York—in addition to the ADCC (Type 4 Operations Building) already at the site. The Hancock command post was one the first SAGE centers to come on line. The facility also replaced the Experimental SAGE Direction Center at the Lincoln Laboratory at Hanscom for final testing of the air defense system (see Volume I, Part IV and Volume II, Chapter 12).

The Lincoln Laboratory operated the Cape Cod System from autumn 1953 into June 1954. The Cape Cod System physically replaced the MEW-Digital Radar Relay (DRR)-Whirlwind system that had transmitted data from MEW Hill to MIT in 1950. MIT and the Cambridge Research Center considered the Cape Cod System a scaled-down, prototype version of a real-world automated air defense sector. The Cape Cod System formally included a long-range AN/FPS-3 radar,[78] then the workhorse of ADC's air defense net, installed with an improved DRR specifically for joint MIT and Cambridge Research Center testing at South Truro, Massachusetts. The Lincoln Laboratory also designed two gap-filler radars and set these up at Scituate and Rockport, Massachusetts. The Scituate site may have been affiliated with the Fourth Cliff Electronics Research Annex, the Hanscom GSU of the late 1940s in the immediate vicinity. A Rockport Electronics Research Annex dated to 1952.[79]

The new gap-fillers featured improved equipment, including a data transmission system called slowed-down video, and IFF. The Cape Cod System added two more AN/FPS-3 radars at Brunswick, Maine, and at Montauk Point, Long Island, as of early 1954. When finished in 1954, the complete system for the prototype air defense sector had 12 gap-filler radars located between Brunswick and Long Island. The sector additionally included three height finder radars and FIS at three airfields (Hanscom, Otis, and Suffolk). Elements in the Cape Cod System fluctuated, with a group of Navy fighter aircraft at South Weymouth, Massachusetts, taking on the FIS role for a period. Initial flight tests occurred twice a week. In December 1953, the Cape Cod System tracked 48 "enemy" aircraft at one time operating in the "ADDC" at North Truro and the "ADCC" at Hanscom (Building 1301). Strategic Air Command (SAC) also participated in the test and evaluation mission. SAC pilots took the role of the enemy and flew B-47 training flights into the sector. In counterpoint, the Lincoln Laboratory and the Cambridge Research Center manned the air defense command posts in lieu of ADC.[80] Using the expanded Cape Cod defense network of late 1954, MIT's Instrumentation Laboratory at Hanscom Field (the Draper Laboratory in MIT's hangar) tested the concept of live interception (see Plate 68). Personnel transmitted interceptor vectoring commands over data link equipment to a B-26 equipped with an autopilot device linked to the Whirlwind computer at MIT. The autopilot device guided the aircraft to a successful interception in an important first for automated air defense.[81]

As of July 1954, the Lincoln Laboratory renamed the Lincoln Transmission System as SAGE. The Experimental SAGE Direction Center (Building 1302F) was in design as of the previous March.[82] In 1954 too, the FIS alert hangar (Building 1840), readiness dormitory (Building 1728), and Unit A weapons storage (Building 1729) were under construction at Hanscom. The readiness dormitory incorporated a squadron operations function (relatively common) and a flight simulator (uncommon). In early 1952, the Cambridge Research Center had originally planned for a separate squadron operations building (behind the readiness dormitory).[83] Standard readiness maintenance hangars for FIS alert (Buildings 1722, 1724, 1727, and 1730) followed as of January 1955 (design), with completion in 1956 (see Plate 71). Erected as the final component of the Lincoln Laboratory, the Experimental SAGE Direction Center was alternately known as the MIT Digital Computer Laboratory and the XD-1 Command Post. The Experimental SAGE Direction Center was under construction in 1955.[84] Planning, design, and engineering for the first- and second-generation air defense networks in the continental United States continued to overlap in timetables and responsibilities between the Air Force, university research laboratories, and architectural-engineering firms. Progress toward SAGE had been steady from 1943 to 1955.

Parts of the radar mission, as well as the analysis and design of plotting boards and voice communications applicable to air defense, shifted to Griffiss in 1948 through the transfer of the Data Utilization Laboratory (the former Visual Design Laboratory). By the early 1950s, radar R&D was splitting between the Cambridge Research Center and the RADC, leading to the competitive contracts for MIT and the University of Michigan during 1952-1953. Although the Lincoln Laboratory and the Willow Run Research Center both evaluated how improved radars fit into a computerized air defense system, neither explicitly worked on radar hardware. MIT's Cape Cod air defense area expanded into the Experimental SAGE Sector (ESS) (Plate 70). The command post for the sector was the Experimental SAGE Direction Center—Building 1302F (in the Lincoln Laboratory) (see Volume I, Plates 69 and 83). Personnel in the command post focused their activities around the IBM computer contracted for the air defense system, the XD–1. First named the Whirlwind II, the XD-1 went into production as the AN/FSQ-7. IBM built two prototype computers, the AN/FSQ-7 (XD-1) and the AN/FSQ-7 (XD-2). The XD-1 replaced the Whirlwind I (of 1950) as the brains of the Cape Cod System in 1955. IBM and the Air Force assigned the two computers formal designations related to radar electronics equipment: the "FSQ" nomenclature referred to fixed (F) special equipment (S) that had a combined purpose (Q). The AN/FSQ-7, in duplex, would become the operational computer for

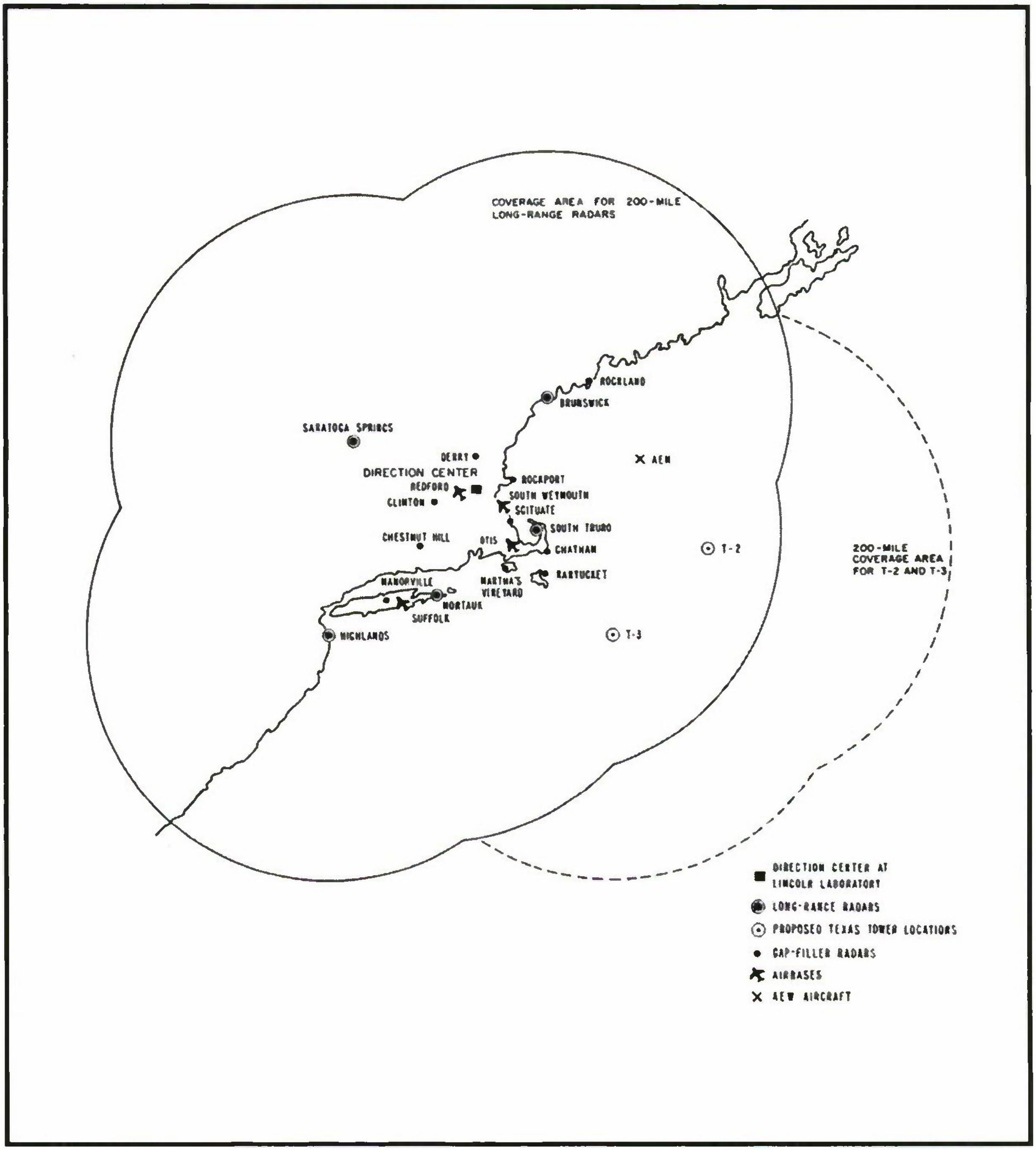

Plate 70: MIT (Lincoln Laboratory) and the Cambridge Research Center, Experimental SAGE Subsector, 1955. The Experimental SAGE Subsector directly continued testing of the Cape Cod MULDAR Net and the Cape Cod System during 1952-1954. In *Operational Plan Semi-Automatic Ground Environment System for Air Defense (Formerly Designated the Transition System)*, 7 March 1955.

the SAGE Direction Center late in the decade, while a similar computer with a specialized display—the AN/FSQ-8—would fill the same role, also in duplex, for the SAGE Combat Center. IBM shipped the first AN/FSQ-8 to the 26th Air Division SAGE Combat Center at Hancock Field in New York in October 1956.[85] The Cambridge Research Center and the Lincoln Laboratory ESS, including its Experimental SAGE Direction Center at Hanscom and the AN/FSQ-7, began shakedown testing in December 1956.[86]

The Experimental SAGE Direction Center at Hanscom was a one-of-a-kind building designed in early 1954. The structure was integral to the Lincoln Laboratory complex at Hanscom and followed the design and construction of the laboratory wings by several years. Full design and engineering responsibility for the Experimental SAGE Direction Center has not been researched, but several important facts should be noted here.

- As was the case for the Types 1-4 Operations Buildings of the ADCC, ADDC, and AC&W radar station network, the SAGE centers were directly tied to the office of air installations (civil engineering) at Headquarters Air Materiel Command at Wright-Patterson.
- Burns & Roe of New York designed the operational SAGE combat and direction centers, but was not involved in the SAGE project in early 1954. Although the original design date for SAGE Combat and Direction Centers is not yet confirmed, it is assumed to be contemporary with a contract to Western Electric in late 1954. This sequence of events leaves a gap of nearly a year between the design of the Experimental SAGE Direction Center at Hanscom and the operational SAGE centers that would define the permanent system. SAGE construction across the continental United States was underway in 1955.[87]
- The contracting structure for the larger SAGE project obscures the division of Air Force and private-sector architectural-engineering responsibilities for the Experimental SAGE Direction Center. The Air Force code-named the initial SAGE efforts by Western Electric and Bell as the Air Defense Engineering Service (ADES).[88] The earliest discovered references to the SAGE buildings are as "Ops-C" (Operations-Combat) and "Ops-D" (Operations-Direction) buildings for the "SAGE ADES Project."[89]

Construction for the Experimental SAGE Direction Center at Hanscom ran from about mid-1954 into spring 1955, followed by the delivery, installation, and testing of equipment. XD-1 computer programming occupied the first half of 1955, while computer instruction continued into spring 1956. The Lincoln Laboratory and the Cambridge Research Center manned the Experimental SAGE Direction Center almost immediately. The Air Force initiated training, operation, and evaluation exercises in autumn 1955 and sustained them until 1958.[90] Like the actual SAGE centers, the Experimental SAGE Direction Center featured thick exterior reinforced concrete walls (one foot thick below ground and eight inches above). The structure also included a complicated roof and flooring system that featured steel girders, concrete block construction, and significant air space between levels. Interior walls were concrete block. The Experimental SAGE Direction Center was three stories tall, with the first floor partially a basement. Windowless, the building featured a small number of louvered panels just above ground level on the west and north elevations. Doorways connected the center to Building 1302D of the Lincoln Laboratory via first- and second-floor enclosed ramps. The footprint of the Experimental SAGE Direction Center was approximately 142 by 122 feet. In comparison, operational SAGE centers featured reinforced concrete walls 10 inches to one foot thick, with footprints 150 feet square (see Volume I, Plates 83 and 85).[91]

The Lincoln Laboratory and the Cambridge Research Center sustained work with SAGE through its buildout in the early 1960s. The Electronic Systems Division (ESD) at Hanscom continued studies in improved air defense command and control for the next generation of automated command posts that followed SAGE, those of BUIC I, II and III of 1960-1968. The RADC had responsibility for the

computer for BUIC II, partnering that center's efforts with the Mitre Corporation at Hanscom.[92] The first operational BUIC II command post was the retrofitted ADDC at North Truro (see Volume I, Part IV). Later efforts also addressed an "airborne BUIC" and led to the Airborne Warning and Control (AWAC) network managed by Tactical Air Command (TAC) as of the middle 1970s. An involvement in data-linked air defense remained strong for Cambridge and the Rome laboratories through the end of the Cold War, and continues in 2000. Both research centers, too, were critical to the development of advanced long-range radar systems for air defense. The ESD at Hanscom worked with Raytheon on the Perimeter Acquisition Vehicle Entry Phased Array Warning System (PAVE PAWS) of the middle 1970s through the remainder of the conflict. The Rome laboratories had handled contracts for the first large phased-array radar, the Bendix AN/FPS-85 at Eglin Air Force Base in Florida, during the 1960s (see Volume I, Part IV, and, Volume II, Chapter 12).

As of ARDC's decision to make Hanscom Field the permanent location for the Cambridge Research Center (and the Lincoln Laboratory), the command began to look at larger questions of improved infrastructure at the World War II base. Not only was there a need to add the laboratory complexes and a FIS alert grouping, but there was also the issue of a maintenance hangar to support any larger aircraft participating in the electronics testing missions. Hangar A, in use by MIT, could handle nothing larger than a B-17 or C (cargo) –46. This situation required personnel to do all work on "B-29-size" aircraft in the open on the parking ramp.[93] While the B-29 did not compare in size to the B-36, for example, the World War II bomber could be anticipated as a candidate for adaptation to testing—just as the B-25 and B-26 had been by MIT's Instrumentation Laboratory. The February 1952 master plan for Hanscom Field illustrated schematic intentions for not only four fighter maintenance hangars, but also two standard Kuljian Corporation double-cantilever maintenance hangars planned side by side, east to west.[94] The Kuljian hangar, designed in three sizes in late 1951 to accommodate SAC's B-36, sometimes served a more multipurpose function for large aircraft. ARDC adapted the double-cantilever hangar at several of its installations, including Hanscom and Edwards. At Hanscom, ARDC elected to erect one double-cantilever hangar instead of two. The command chose the intermediate size of the hangar, capable of housing four B-36s at one time (with partial nose or tail of the bombers protruding). Labeled the "medium bomber" hangar, the intermediate double-cantilever hangar most often went up for the B-47. ARDC adapted the hangar for Hanscom Field in September 1953[95] (Plate 71). The Kuljian hangar (Building 1715) replaced the World War II Hangars A and B (see below). The Cambridge Research Center also added a standard Air Force Reserves hangar (Building 1716).[96]

Master plans for Hanscom continued to include a second double-cantilever hangar well into 1956, although by October 1957 the Cambridge Research Center had abandoned the more expansive idea.[97] In August 1954, ARDC and the Directorate of Installations at Headquarters Air Force discussed the planned pair of double-cantilever hangars for Hanscom. The problem revolved around new requirements for 250 feet of apron pavement bracketing the openings on each side of all double-cantilever hangars erected after this date. Other spatial requirements of 425 feet between grouped double-cantilever hangars and a 125-foot separation from existing buildings made it impossible for the Air Force to meet all of the criteria at Hanscom—and still have the second hangar remain on Air Force property. ARDC asked for a waiver to erect two double-cantilever hangars at Hanscom only 350 feet apart.[98] Possibly, the Directorate of Installations did not grant the waiver, or the Cambridge Research Center concluded that the installation did not need the hangar. The double-cantilever and reserves hangars occupied a site overlaying the World War II northwest-southeast runway.[99] Construction, however, was slow. Erection of the Kuljian double-cantilever hangar required about two full years at most Air Force installations (see Volume I, Part IV), a timetable somewhat more complicated at Hanscom due to the middle 1950s extension of the primary east-west runway in 1953 and the reconfiguring of flightline aprons. As late as May 1955, two pair of moveable B-50 wing docks (appropriate also to the B-29) sat along the lower western edge of the abandoned northwest-

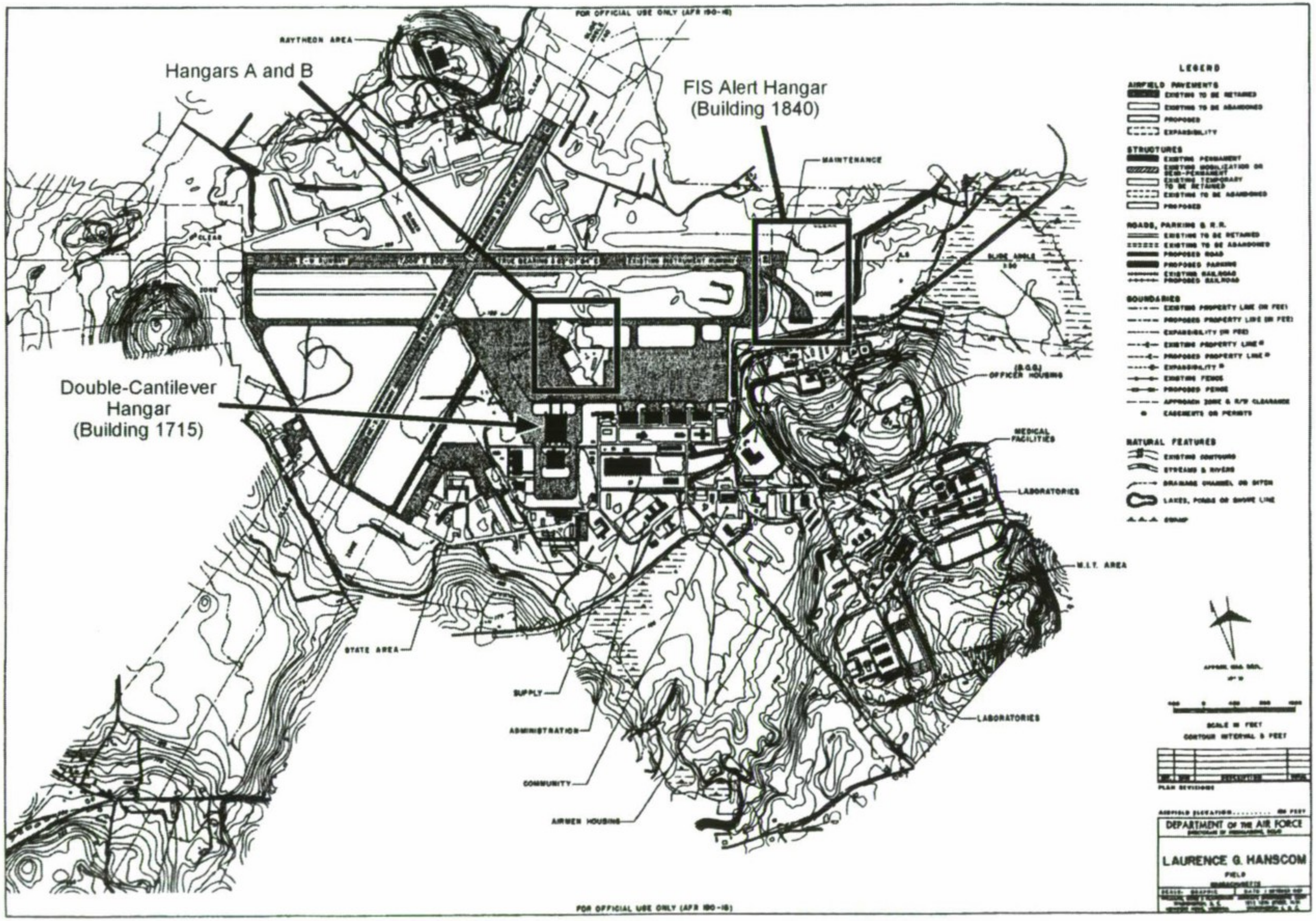

Plate 71: **Directorate of Installations, Headquarters United States Air Force. Master Plan for Laurence G. Hanscom Field, October 1957. Annotations added for Hangars A and B, the double-cantilever hangar (Building 1715), and the FIS alert hangar (Building 1840). Courtesy of Civil Engineering, Hanscom Air Force Base.**

southeast runway. ARDC used the docks for open-air maintenance of its bombers until the double-cantilever hangar was operational.[100] During the construction, the World War II Hangars A and B remained at their original location on the flightline. As of autumn 1957, an unfinished new aircraft parking apron completely encroached upon these two structures (see Plate 71).[101] Only in 1958 did the Air Force physically relocate Hangar A, moving the structure about three-quarters of a mile.[102]

The improved configuration at Hanscom Field featured two runways that were both extremely short for the Cold War era. The Air Force lengthened the east-west runway only to 7,000 feet, with a 200-foot width, and also extended the northeast-southwest runway to 5,500 feet (with a 200-foot width). The shorter runway was the more substantial (for bombers like the B-25, B-26, and B-29) and featured 10 inches of concrete over a 35-inch base of non-frost susceptible sand and gravel. The 7,000-foot runway provided a mile-long center section (from World War II) of three-inch bituminous concrete over six inches of crushed stone, atop a sub-base of six inches of sand and gravel laid upon 45 inches of sand fill. The major eastern extension of the longer runway continued this treatment for the first 1,000 feet before transitioning to three inches of tar over six inches of crushed stone, laid over a six-inch sub-base of sand and gravel atop 30 inches of sand fill. The easternmost end of the runway featured only two inches of bituminous concrete over six inches of sand and gravel. The Air Force reserved the heaviest construction for the aprons bracketing the double-cantilever hangar: 13 inches of concrete over a base of 35 inches of non-frost susceptible sand and gravel.[103] These runway lengths and construction details indicated a limited fighter aircraft mission, and one even more constrained for heavier bombers. In particular, the extremely conservative approach foreshadowed that future missions at the installation would not focus on aircraft. The late 1950s expansion at Hanscom also severely limited the assignment of tenant missions that relied on modern planes. The runway infrastructure of Hanscom Field was most appropriate for bombers of the late World War II period.[104]

Beginning in 1953-1954 and steady into the next decade, the Cambridge Research Center (Cambridge Research Laboratories after 1960) added a number of specialized individual laboratories that evolved into a mixed complex of radar, tactical air control, and geophysics clusters just west of Katahdin Hill. The earliest buildings in the area were radar test structures on or next to the hill. The first was a Thermal Radiation test facility, erected as a Stran Steel prefabricated unit on Katahdin Hill in late 1954. ARDC continued to augment the site for the Cambridge Research Center. As of early 1955, the command constructed a radar transmitter and receiver just south of the hill (Building 1119). By September, Joseph L. Paley, a Boston consulting engineer, completed drawings for the T.A.C. (Tactical Air Control) Building (Building 1121). Tactical air control centers were primarily a project of the RADC. These centers had many parallels to SAGE (see Volume II, Chapter 12). Congdon, Gurney & Towle, Inc., another Boston engineering firm, designed a Propagation Studies Laboratory (Speech Research Laboratory) and a Heavy Radar Assembly Building at about this same time[105] (Buildings 1120 and 1118). The Cambridge Research Center next erected structures for a more concentrated geophysics compound. The geophysics laboratory grouping grew consistently to the northwest of Katahdin Hill, but accrued one laboratory at a time beginning with the addition of an Electronic Radio-Chemistry Laboratory in 1956 (Building 1124).[106] In 1957, the Cambridge Research Center added an Airborne Electronics Laboratory (Building 1122) to the geophysics area.[107]

During this same period, the Cambridge Research Center added 22 GSUs (excluding housing complexes). Most of the individual test locations dated to the late 1950s and were of short duration. These sites included:

- Brant Rock Electronic Research Annex near Marshfield, Massachusetts (1952-1966);
- Plum Island Radar Annex near Newburyport, Massachusetts (1952-1968);

- Blue Hills Research Annex at Milton, Massachusetts (1955-1962);
- Fort Dearborn Electronics Research Annex at Fort Dearborn, Massachusetts (1955-1959);
- Fort Devens Geophysics Research Annex at Fort Devens, Massachusetts (1956-1962);
- Sagamore Hill Electronics Research Annex at Hamilton, Massachusetts (1957-current);
- Squantum Electronics Research Annex near Quincy, Massachusetts (1957-1960);
- Vernalis Geophysics Research Annex in the vicinity of Vernalis, California (1957-1962) [see Volume I, Part III];
- Mishaum Point Electronics Research Annex at South Dartmouth, Massachusetts (1958-1964);
- Oak Hill Electronics Research Annex at Littleton, Massachusetts (1958-1962);
- Waltham Electronics [later, Geophysics] Research Annex #1 at Waltham, Massachusetts (1958-1965);
- Waltham Electronics Research Annex #2 at Waltham, Massachusetts (1958-1970);
- Weston Geophysics Research Annex at Weston, Massachusetts (1958-1965);
- Chestnut Hill Geophysics Research Annex #2 at Beacon Hill, Massachusetts (1959-1961);
- East Boston Geophysics Research Annex at East Boston (1959-1960);
- Fort Tilden Fuel Test Annex #2 near Brooklyn, New York (1959-1962);
- Navajo Geophysics Research Annex at Flagstaff, Arizona (1959-1964);
- New Boston Tracking and Data Acquisition Annex at Mount Vernon, New Hampshire (1959-1966);
- Rye Ledge, New Hampshire (1959-1965);
- Spot Pound Geophysics Research Annex #1 at Stoneham, Massachusetts (1959-1975);
- Strawberry Hill Electronics Research Annex near Acton, Massachusetts (1959-1969); and,
- Waltham Geophysics Research Annex #2 at Waltham, Massachusetts (1959-1970).[108]

As of 1959, the complexity of the laboratories designed for the geophysics area at Hanscom Field increased significantly. The Sumner Sollitt Company, with architect Frederick Stanton, designed a positive ion accelerator and gamma source hot cell for the Cambridge Research Center in July 1959 (Building 1126). The structure, alternately known as the Van de Graaff Cobalt Facility, featured an accelerator target area below the radiation source, a manipulator area, and a control room. Research personnel used the Cobalt-60 hot cell to conduct studies of radiation effects and hardening on materials and devices (Plate 72). ARDC acquired another Cobalt-60 test facility at this same time, at Brooks Air Force Base in Texas. The Brooks facility first operated under Air Training Command and supported ARDC studies in aeromedicine (see Volume II, Chapter 2). Other physics laboratories went up on the geophysics site at Hanscom during the early 1960s. In mid-1961, a Plasma Physics Laboratory (Building 1138) featured a shock tube and ballistic range (with control room), a high-density plasma room, an environmental chamber, and a plasma jet area on the first floor, and a mass spectrometer, low- and high-powered microwaves, a high-speed photographic room, a high-temperature plasma area, electronics and tube shops, and a materials preparation room on the second floor. Special-purpose environmental chambers existed across ARDC, as did shock tubes and ballistic ranges. The Cambridge Research Laboratories added a linear accelerator and a Radiation Physics Laboratory to the complex between 1961-1963 (Buildings 1127 and 1128). All of these buildings were of simple modern design commonly found in science laboratories of their period. Exterior details included porcelain metal panels and aluminum trim, as well as cast-block lettering for signage. Design and construction of the group of aeromedical laboratories at Brooks, for example, also featured this type of detail (see Volume II, Chapter 2).[109]

ARDC / AFSC added test structures at Hanscom from this point forward. A second geophysics and upper air research area of loosely clustered buildings was under construction as of 1953 to the north of the Lincoln Laboratory. To support the balloon studies of the upper atmosphere underway through

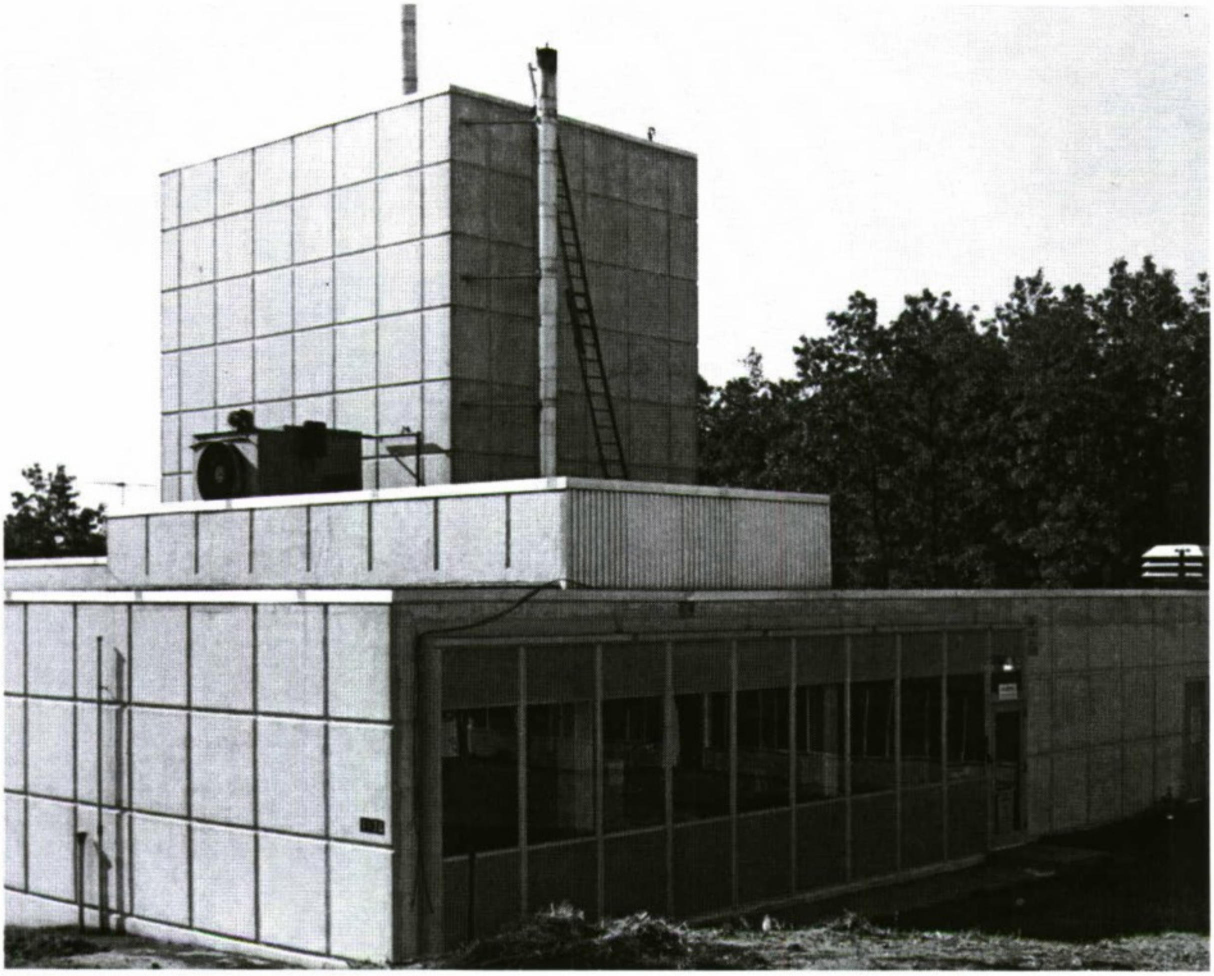

Plate 72: The Sumner Sollitt Company, with Frank Stanton. Van de Graaff Cobalt Facility (Building 1126), Hanscom Field, 1959. Undated view. Courtesy of the History Office, Hanscom Air Force Base.

the Cambridge Research Center (see Volume I, Part III), ARDC erected a meteorological laboratory for experimental balloon flights (the Rawinsonde [radar wind sounding] Building) in the middle of that year (Building 1440) (Plate 73). As of 1956-1957, ARDC added an atmospheric thermal radiation field test facility (Building 1429), a geophysics laboratory (laser research laboratory) (Building 1436), and an electromagnetic laboratory (optical physics laboratory) (Building 1431).[110] Each of these structures were visually typical of their period, but housed scientists carrying out highly technical experimentation in geophysics and upper air research. In the electromagnetic laboratory, for example, scientists conducted computer modeling for the infrared properties of the atmosphere. The formal ARDC designations for the geophysics laboratories at Hanscom often indicated a generic use, while actual activities during successive, well-defined periods were quite specific. A high-profile instance of this situation within the "1400" area at the installation was Building 1435 of October 1958.[111] Drawings described the structure only as a Data Analysis Laboratory and indicated a general science-laboratory use. During its earliest years, however, Building 1435 functioned as a training spacetrack control center that was part of the Space Detection and Tracking System (SPADATS) project initiated in response to the Soviet Union's successful launching of Sputnik in October 1957. Between its dedication in early 1960 and July 1961, Building 1435 also served as the National Space Surveillance Control Center while the permanent Space Control Center for

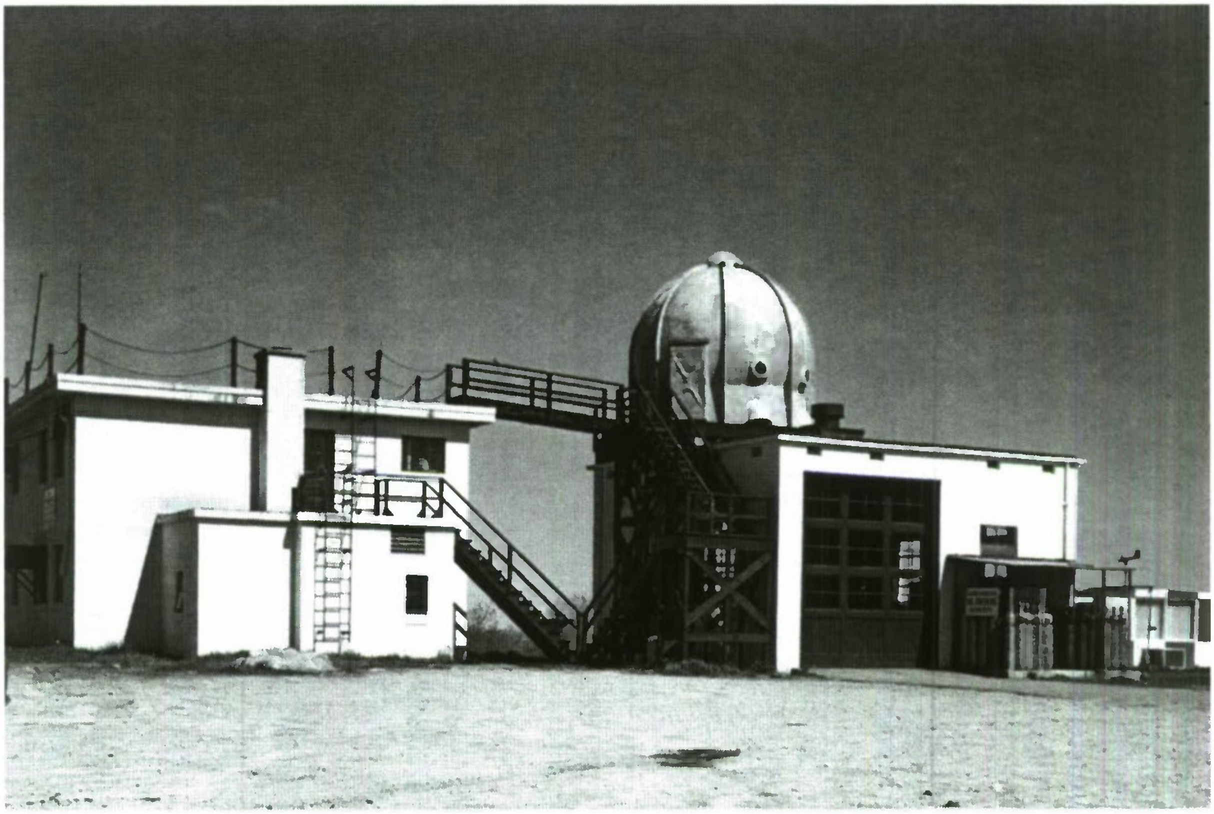

Plate 73: Rawinsonde Facility (Building 1440), Cambridge Research Center, Hanscom Field, 1953. Undated view. Courtesy of the History Office, Hanscom Air Force Base.

SPADATS was under construction in ADC's hardened complex inside Cheyenne Mountain in Colorado (see Volume I, Part IV).

The changing dynamics of electronics and geophysics research within the Cambridge Research Laboratories also called for remodeling buildings of the 1950s for new missions of the subsequent decades, and on occasion for adding both highly innovative and standard hangars at the installation. The layering of research sometimes mandated a completely new interior for a building. One example is the Seismic Gravity Pier Facility (Building 1111). While the original structure dates to the 1950s, AFSC remodeled the interior of the modest building during the late 1960s to accommodate seismic test equipment. The remodeling included retrofitting deep reinforced concrete piers below the foundation. Military seismic facilities of this period monitored both natural events and nuclear weapons testing.[112] An example of an unusual hangar added during the late 1950s was the Raytheon electronics test hangar erected on the periphery of the airfield. In 1956, the American engineering community had begun to employ cable suspension to enhance double-cantilever support for aircraft hangars with increasingly longer cantilevered members (required to create more open hangar interiors). These hangars were very large, most often located at major civilian airports. As of 1959, both the Air Force and the Navy had turned to cable-assisted cantilevers, with a focus on an augmentation of single cantilever systems. A design of Willgoos, Strobel, Panero & Knoerle for a cable-assisted Naval Air Station hangar that year was especially notable in the military community.[113] The Raytheon test hangar at Hanscom Field, designed by the Boston engineering firm of Fay, Spofford & Thorndike, dates to late 1958 or early 1959, and is also an early military use of the cable-assisted cantilever—here, in a double configuration cantilevered from a three-story center section of shops and offices[114] (Plate 74).

Plate 74: Fay, Spofford & Thorndike. Raytheon Electronics Test Hangar, Hanscom Field, 1958-1959. In *The Military Engineer*, July-August 1959.

At Hanscom Field of the late 1950s and early 1960s, three examples of the cable-assisted hangar exist. The Raytheon structure was actually two side-opening aircraft hangars back to back, with each built to accommodate a B-50. The interior center shops and offices also included aircraft nose pockets that effectively lengthened the available work space for electronics modification of B-50s pulled into the hangar. Raytheon, like MIT, required quality interior clearspace for the development of electronic devices and their integration into test planes at Hanscom Field, but did not need exceptionally large hangars. Aircraft adapted for electronics testing by both Raytheon and MIT were vintage World War II bombers (appropriate for the runways, as noted above), with the largest and heaviest of the planes either the B-29 or B-50 (a bomber of the very early Cold War based directly on the B-29). Cantilevers for the Raytheon hangar were 86 feet from the center, not as long as the cantilevers of the 1951 Kuljian double-cantilever hangar (Building 1715 at Hanscom), for example, but of considerable note for the creation of interior space. The Navy Bureau of Yards and Docks, in a role paralleling that of the Army Corps of Engineers for the management of military construction, supervised the erection of the Raytheon hangar at Hanscom. (The Navy's involvement is noteworthy, given that agency's own focus on cable-assisted hangar systems in this exact time period.)[115] A derivative, but still quite important, example of the cable-assisted hangar was a standard Air Force large aircraft maintenance dock of 1964 by the Kansas City architectural-engineering firm of Burns & McDonnell.[116] AFSC erected two of these hangars at Hanscom Field, Buildings 1718 and 1720, near the Kuljian double-cantilever hangar. In the cases of the original double-cantilever hangar, the Raytheon hangar, and the large-aircraft maintenance docks, the goal was to provide as open an interior as possible for workspace in which to modify test aircraft. Workspace needed to be generous, as modifications were not routine, nor were space needs entirely predictable.

As the SAGE project matured after the middle 1950s, R&D at Hanscom Field also underwent the first of a number of complex organizational changes. In 1957, the Air Force established the Air Defense Systems Management Office (ADSMO), including detachments from ARDC, Air Materiel Command, and ADC. The Air Force redesignated the organization as the Air Defense Systems Integration Division (ADSID) the next year. Late in 1959, ARDC activated the Air Force Command and Control Development Division (AFCCDD) at Hanscom Field, while Air Materiel Command nearly simultaneously initiated the Electronic Systems Center (ESC) as its counterpart on base. In 1960, the Air Force dissolved the Cambridge Research Center, assigning its Geophysics and Electronics Directorates as detachments to a newly set up Air Force Research Division. Changes continued to be rapid, and before the close of the year the Cambridge Research Laboratories replaced

Detachment 2 of the Air Force Research Division (returning to the center's name from the late 1940s). The Air Force also discontinued the ADSID in 1960. With the redesignation of ARDC as AFSC in 1961, and Air Materiel Command as AFLC, the reshaping of the air defense, electronics, and geophysics missions at Hanscom shifted yet again. At that time, the Air Force grouped the ESC and the AFCCDD together under AFSC to form the ESD and placed the Cambridge Research Laboratories under the Office of Aerospace Research—that office assigned to the Air Force Chief of Staff. By early 1964, a second failed attempt to move a major portion of the electronics R&D mission from Hanscom Field to Griffiss Air Force Base in New York was in progress due to NASA's desire to use facilities at Hanscom to develop an electronics research center in the Boston area. After this date, the Cambridge Research Laboratories and the ESD became the two major R&D foci at Hanscom Field, stabilizing in name changes and missions.[117]

As of the 1960s, the air defense command and control mission, including the development of increasingly sophisticated sensors, expanded from the joint work of the Cambridge Research Center and Lincoln Laboratory toward SAGE, to a more complex and encompassing effort that included command, control, communication, computers and intelligence (C^4I) mission. From this point forward, C^4I efforts at Hanscom and the laboratories at Rome, New York, overlapped significantly. In organizational hierarchy, the RADC became subsumed under ESD at Hanscom with the shift from ARDC to AFSC in 1961. By 1961, 13 electronic systems program offices were in place at Hanscom Field. Project involvement of this type continued to increase during the later Cold War (through the RADC as well as the ESD) and included efforts for:

- the Ballistic Missile Early Warning System (BMEWS);
- the Nuclear Detonation Detection and Reporting System (NUDETS);
- the Air Weapons Control System;
- the Air Communications System;
- SPADATS;
- the Electromagnetic Intelligence System;
- the Post-Attack Command Control System (PACCS);
- the development of several command and control systems for Headquarters Air Force and individual commands;
- the Airborne Long Range Input (ALRI) Program;
- the Sea-Launched Ballistic Missile (SLBM) Detection and Warning System (leading to PAVE PAWS);
- BUIC;
- program efforts for overseas air defense systems;
- an upgraded Arctic communications system (the Northern Area Communications System);
- the Apollo Range Instrumented Aircraft (ARIA) program;
- development of long-range weather radars and forecasting stations for international locations;
- AWACS;
- the Survivable Low Frequency Communications System;
- the Montana Large Aperture Seismic Array (LASA);
- the Over-the-Horizon Backscatter (OTH-B) Radar program;
- contract management for large phased-array radar development, work toward the JSS (follow-on to SAGE and BUIC III);
- involvement in the Strategic Defense Initiative (SDI) program; and,
- the Joint Surveillance Target Attack Radar System (STARS) project.[118]

The early and middle 1960s also were a period of GSU expansion for Hanscom Field, and included new facilities at the:

- Clear Missile Early Warning Station at Nenana, Alaska (1961-[unknown disposal date, post 1982(?)]) (currently the site of the most recent American large phased-array radar, operational in 2001);
- Wilmington Geophysics Research Annex at Wilmington, Delaware (1961-1975);
- Bedford Electronics Annex at Bedford, Massachusetts (1962-1976);
- Chico Research Site at Chico, California (1963-[unknown disposal date, post-1982]);
- Ipswich Data Collection Laboratory Annex at Ipswich, Massachusetts (1963-1974);
- Sudbury Antenna Farm Annex at Sudbury, Massachusetts (1966-current); and,
- Sudbury Electronics Research Annex near Marlboro, Massachusetts (1966-[unknown disposal date, post-1982]).[119]

Hanscom's runways supported only minimal aircraft operations for electronics and air defense flight testing during the first three decades of the Cold War, and in 1973 flying activities at the base ceased. The next year, Hanscom Field became Laurence G. Hanscom Air Force Base (shortened to Hanscom Air Force Base in 1977), a very late designation parallel to the situation for ARDC / AFSC's missile and space R&D center at Los Angeles Air Force Station (which did not become an Air Force base until 1989). The largest aircraft at Hanscom had been the B-29 / B-50 and C-124, while the most advanced fighter operating at the installation was the F-86L of the middle 1950s. The Hanscom laboratories continued their electronics and geophysics R&D, with the RADC establishing a detachment on base as of 1976 carved from the microwave physics and solid-state sciences formerly within the Cambridge Research Laboratories. As of 1976 also, the electronics components of the Cambridge Research Laboratories organizationally fell under the RADC (including efforts sustained at Hanscom). Air Force redesignations followed, with the remaining laboratories becoming the Air Force Geophysics Laboratory in 1976. A larger reorganization of Air Force laboratories was underway (see Volume I, Part II), and in 1982 AFSC assigned the Air Force Geophysics Laboratory to the Air Force Space Technology Center at Kirtland Air Force Base in New Mexico. The command tiered the Air Force Space Technology Center beneath Space Division in Los Angeles (then at Los Angeles Air Force Station). The evolution toward Air Force super laboratories continued, and the Geophysics Laboratory became a part of the Phillips Laboratory, also headquartered at Kirtland, in 1990 (in 2003, the Air Force Research Laboratory after further changes in 1997).[120]

Geophysics R&D at Hanscom during the final three decades of the Cold War continued to make sophisticated advances in the areas of meteorology, atmospheric physics, and solar-terrestrial studies. By the middle 1970s, geophysical programs at the installation focused more closely on weapons, surveillance, communications, and navigation systems, taking the "form of prediction codes, models, atlases, data bases, design and test standards, feasibility studies, software, tactical decision aids, and prototype hardware." The installation picked up two final GSUs, the Sudbury Test Annex #2 at Sudbury, Massachusetts (1970-1972) and the Kittson County Weather Research Site in Donaldson, Minnesota (1971-1974).[121] AFSC transferred the geophysical products developed at Hanscom to other Air Force commands and continued to sustain a long-standing relationship to the Air Weather Service. Upper air studies of the early Cold War evolved as research into the traditional weather of the troposphere and analysis of space weather. The Air Force Geophysics Laboratory (and later, the Hanscom geophysics component of the Air Force Research Laboratory) defined tropospheric and space "weather" as "disturbances in the Earth's upper atmosphere [troposphere] and in near-Earth space...largely caused by the Sun." Weather studies at Hanscom contributed to the Air Force's ability to accurately predict the operational environment for its weapons systems. An understanding of atmospheric science also supported the Air Force in its refinement of detection and targeting

systems of the later Cold War. A number of the geophysics programs undertaken at Hanscom also directly coordinated with the needs and endeavors of NASA[122] (see Volume I, Part IV).

Key Associated Architects and Engineers

Architectural-engineering firms of national significance associated with key buildings and structures at Hanscom Air Force Base during the Cold War included several that were chiefly noted for their designs of hangars built for ADC and SAC programs, or were firms of long standing in the practice of American architecture. Several of these firms are discussed in Volume I or in other chapters of Volume II, as noted:

- Burns & McDonnell, of Kansas City;
- Burns & Roe, of New York (Volume II, Chapter 1);
- Cram & Ferguson, of Boston (Volume I, Part IV);
- Fay, Spofford & Thorndike, of Boston;
- Kuljian Corporation, of Philadelphia (Volume II, Chapter 3);
- Shepley, Bulfinch, Richardson and Abbott, of Boston (Volume I, Part IV); and,
- Strobel & Salzman, of New York.

Burns & McDonnell

Founded in 1898, the partnership of Stanford University engineering graduates Clinton Burns and Robert McDonnell focused their first efforts on water and sewer systems for towns surrounding Kansas City. Initial commissions included ones for hydroelectric power plants. By the early 20th century, Burns & McDonnell had expanded to design a hydroelectric power plant in Mexico. A concentration on hydroelectric plant and water reservoir engineering continued into the 1930s, with design of water systems in Washington, Arizona, Oklahoma, and Illinois. In 1935, Burns & McDonnell supervised the construction of the largest electric distribution system in the United States at Knoxville, Tennessee, in conjunction with the Tennessee Valley Authority (TVA). This effort would also become integral to the Manhattan Project facilities built in Oak Ridge, Tennessee, in 1942. During World War II, the firm designed the Smoky Hill Army Airfield (later renamed Schilling Air Force Base) in Salina, Kansas. The air base commission began a long career for the firm engineering military and civilian aviation structures. As of the late 1950s, Burns & McDonnell also designed aircraft engine test cells, including several efforts for the Navy. During the 1950s and 1960s, Burns & McDonnell engineered an overhaul and maintenance facility for Trans World Airlines (TWA) in Kansas City, as well as executing master plans for Dulles Airport in Washington, D.C., and the Kansas City Airport. The TWA hangar was a cable-suspension structure that immediately predated the firm's cable-assisted large maintenance dock for the Air Force (Buildings 1718 and 1720 at Hanscom). The hangar in Kansas City featured supporting cables anchored in the center of the structure in 30-foot deep reinforced concrete walls. The two suspended roofs of the hangar were each 150 feet wide and over 800 feet long.[123] The New York engineering firm of Amman & Whitney consulted with Burns & McDonnell on the project. (Amman & Whitney was another very important firm working for Headquarters Air Materiel Command: see Volume I, Part II). Burns & McDonnell continues to be known for its design of power plants and related industrial construction into the present. The firm also handles significant work overseas. As of 1998, Burns & McDonnell had over 1,300 employees and sustained its position as a major American architectural-engineering firm.[124]

Fay, Spofford & Thorndike

Founded in 1914, Fay, Spofford & Thorndike is only minimally discussed here. Charles Milton Spofford (born 1871) was an MIT civil engineering graduate who had first worked as a draftsman for the Phoenix Bridge Company in Phoenixville, Pennsylvania. During the early 20th century, Spofford taught engineering at MIT and subsequently at the Polytechnic Institute of Brooklyn. Thereafter, he returned to MIT until 1940, first as a professor of civil engineering and then as head of the civil engineering department. Fay, Spofford & Thorndike evaluated the strengths of major Boston area bridges; served as consulting engineers for the TVA during 1934-1935; undertook the World War II design of the Boston Army Supply Base; and, engineered a variety of important New England bridges.[125] The firm's design of the cable-assisted cantilever-truss flight test hangar for Raytheon at Hanscom Field in 1958 was of parallel achievement to the efforts of Strobel & Salzman and Burns & McDonnell during the same period. Both Fay, Spofford & Thorndike and Strobel & Salzman were tied to innovative work for the Navy Bureau of Yards and Docks.

Strobel & Salzman

The Strobel & Salzman firm handled significant Army, Navy, Marine, and Air Force assignments during 1951-1956. Willgoos, Strobel, Panero & Knoerle continued work for the Navy as of about 1959. Engineer Peter A. Strobel initially appears in 1947 as the consulting design engineer for the Luria Steel and Trading Corporation of New York. In that year, Strobel designed one of the largest bolted, steel arched-truss hangars up to that date, for the Office of the Chief of Engineers, United States Army. The three-hinged arch structure was 200 feet long, spanned 194 feet and featured a rise of 45 feet. The Army commissioned the hangar for the B-29. It was a portable structure, planned for use overseas. The American engineering community showcased the hangar as a major achievement due to its conservation of steel, its simplicity of design, and its interchangeable parts. (The portable B-29 hangar had only nine different parts, in total.)[126] In 1951, Strobel was the consulting engineer for Luria Engineering in the design of the enclosed B-36 nose dock, an even more noteworthy accomplishment. The best remaining examples of the very rare B-36 dock are extant today at Ellsworth Air Force Base in South Dakota. (Luria was also responsible for the B-47 nose dock just several years later. The B-47 dock featured a swept-wing design reflective of the medium bomber. It is likely that Strobel continued to consult with Luria for this dock as well, of which only photographs survive.) Peter Strobel was born in Denmark and graduated as a civil engineer from the Royal Technical University of Copenhagen. After immigrating to the United States, Strobel undertook both military and civilian engineering projects as of about 1929.[127]

The firm of Strobel & Salzman also consulted for a prominent assignment for the Marine Corps. Strobel & Salzman provided engineering expertise to the Mitchell Mobilhangar Corporation of New York, parallel to its role with Luria, for a clamshell hangar at the Marine Corps Air Station at Cherry Point, North Carolina. Completed during 1950-1951, the Marine Corps hangar opened and closed in two 100-foot equilateral triangular halves that rolled on embedded railroad ties set in reinforced concrete. A maximum separation of 172 feet between the opened halves allowed aircraft to enter and leave the structure, with a total opening time of only three minutes. The hangar was self-sufficient and fully protective of its aircraft when closed, and even included its own power generators. The Marine hangar was "demountable and could be moved from place to place as war or defense demands might require." John L. Mitchell, President of Mitchell Mobilhangar, marketed his portable nose dock widely across the Department of Defense, with a larger model proposed as a multipurpose dock for the B-36, B-47, and B-52. In 1950, Mr. Mitchell presented his ideas for the nose dock directly to General Curtis E. LeMay at Headquarters SAC. LeMay requested a pilot model of the Mobilhangar for erection at either Ellsworth or Limestone (Loring) Air Force Bases, but then decided to await the construction of the smaller version at Cherry Point for the Marines. Subsequent to an operational test

at Cherry Point—with representatives of SAC, Military Air Transport Command and Air Materiel Command present—the Air Force decided not to procure the innovative structure.[128] (The Mobilhangar was the small version of the nose dock. The Mobildock was larger, but identical in design and intended for the B-36, B-47, B-52, or C-124.[129]

In April 1951, Strobel & Salzman continued their creative engineering of aircraft hangars through their design for the standard ADC alert hangar. Two years later the firm designed an upgraded standard readiness maintenance hangar for ADC alert configurations; three Army maintenance hangars in 1955; a second-generation ADC alert hangar in 1956; and, an ADC alert ready shelter in 1957. (ADC erected the shelter chiefly across the northern tier of the continental United States). The Air Force and Army constructed each of these hangars many times. During several years after the middle 1950s, Strobel left the firm to serve as Commissioner of the Public Buildings Service (PBS). PBS was the lead federal agency for government building design. Engineer Strobel returned to the design and engineering of hangars at the end of the decade with his innovative cable-assisted cantilever-truss hangar at Andrews Air Force Base. During this period, Strobel was a partner in Willgoos, Strobel, Panero & Knoerle. The November 1959 design became a standard one for the Navy and was among the earliest cable-assisted cantilever hangars then underway.[130] Guy Panero, of the late 1950s firm, also had made a notable previous contribution in military design as the Army Corps of Engineers contractor for an underground pilot plant of the late 1940s—paralleling the efforts of J. Gordon Turnbull for Air Materiel Command (see Volume I, Part III).

---

[1] Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). The reader can trace the broad patterns of lineage for the installation in the Hanscom Air Force Base chapter. The chapter includes the sequence of installation names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base.

[2] *Ibid*, 221-225.

[3] *Ibid*, 224-225.

[4] Air Materiel Command, *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 2-11.

[5] The author has been unable to decipher HANG-N-A with certainty. "HANG" is likely a shortened form of "hangar," while "N-A" may be "Navy-Army."

[6] Three of these structures are demolished today. Hangar A remains, moved to a new location at Hanscom in 1958. Hangar A is not Air Force property today.

[7] BEMI-A-A stands for Base Engineering Maintenance and Inspection – Army Air Forces.

[8] "AN/CPS" incorporates standard radar and electronics coding into its acronym. "AN" is the generic identification for "Army-Navy" and is common to all radar. The second three letters in the nomenclature reference the type of installation, the specific equipment, and its purpose. "C" indicates "air-transportable;" "P" denotes "radar;" and, "S" signifies "detection" and / or "range and bearing."

[9] *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 17. MEW Hill is also the likely location for the Fighter Control Center at Bedford Field of 1944—with MIT taking over whatever facilities that I Fighter Command had erected at its site and adapting them for radar testing.

[10] Karen J. Weitze, *Eglin Air Force Base, 1931-1991; Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 25-29.

[11] The Air Force Materiel Command History Office at Hanscom Air Force Base maintains an excellent collection of dated historic photographs.

[12] United States Engineer Office: "Bedford Air Base Electrical Distribution System Areas A and C," "Bedford Air Base Electrical Distribution System Area B," both, August 1942; "Building Type BEMI-AA Modified," 12 August 1943; and, "Bedford Airdrome Drainage System," 18 September 1945; "Schedule and Plan of Building Area 1," *Basic Information Folder Hanscom Airport Bedford, Mass.*, April 1951; and, Julie L. Webster, Michael A. Pedrotty, and Aaron R. Chmiel, *Historical and Architectural Overview of Military Aircraft*

Hangars: A General History, Thematic Typology, and Inventory of Aircraft Hangars and Associated Buildings on Department of Defense Installations, USACERL Technical Report 96, Draft (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, March 1996), *passim.*
[13] *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 13-14.
[14] Mueller, *Active Air Force Bases*, 1989, 222-223.
[15] Air Materiel Command, *Unit History of Watson Laboratories Cambridge Field Station 1 July – 31 December 1946*, 11.
[16] *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 14.
[17] The MIT demountable hangar is not Air Force real property today.
[18] Webster, Pedrotty, and Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars*, 1996, elevation and plan.
[19] Commonwealth of Massachusetts State Airport Management Board, "High & Medium Intensity Runway Lighting Master Plan," 1 March 1950.
[20] Air Force Systems Command, *History of Air Force Systems Command 1 July 1969 – 30 June 1970*, volume 1, Air Force Cambridge Research Laboratories organization chart; Mueller, *Active Air Force Bases*, 1989, 222.
[21] Matt Kiersteadt, "Draft Inventory and Evaluation for the Draper Laboratory (MIT Hangar)," Pawtucket, Rhode Island: The Public Archaeology Laboratory, July 2001.
[22] *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*, 15-23.
[23] The AN/CPN-18 was an air-transportable ("C") radar ("P") that functioned as a navigational aid ("N").
[24] Air Materiel Command, *Unit History of Watson Laboratories Cambridge Field Station 1 January – 31 March 1947*, 13-21.
[25] Air Materiel Command, *Historical Data Cambridge Field Station 3160th Electronics Station 1 January – 30 June 1949*, volume 9, 52-54.
[26] William J. Smith, Robert M. Barrett, Frederick Kline, and Lawrence C. Mansur, *Proposed Fence System for Air Surveillance of Continental United States*, Cambridge Field Station Report No. 1-34, 12 May 1947, in *Unit History of Watson Laboratories Cambridge Field Station 1 January – 31 March 1947.*
[27] David F. Winkler, *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program* (Champaign, Illinois: United States Army Construction Engineering Research Laboratories for Air Combat Command, June 1997), 9-13.
[28] The Cambridge facilities at Sacramento Peak are long since closed. In 2003, the facilities are part of the National Solar Observatory.
[29] Air Materiel Command: *Unit History of Watson Laboratories Cambridge Field Station 1 April – 30 June 1947*, 8, 19-24; *Unit History of Watson Laboratories Cambridge Field Station 1 July – 30 September 1947*, 11, 15-16, 34, 116-125; and, *Unit History of Watson Laboratories Cambridge Field Station 1 October – 31 December 1947*, 36-44, 47-49.
[30] *Unit History of Watson Laboratories Cambridge Field Station 1 July – 30 September 1947*, 26; Mueller, *Active Air Force Bases*, 1989, 222.
[31] Air Materiel Command, *Unit History of 4135th Air Force Base Unit Cambridge Field Station 1 January – 30 June 1948*, 31.
[32] Mueller, *Active Air Force Bases*, 1989, 222-223.
[33] *Unit History of Watson Laboratories Cambridge Field Station 1 July – 30 September 1947*, 42-44.
[34] *Unit History of Watson Laboratories Cambridge Field Station 1 January – 31 March 1947*, 19. The AN/MPS-3 is electronics equipment defined as "ground use, mobile" (M), "radar" (P), "detection and / or range and bearing" (S).
[35] *Historical Data Cambridge Field Station 3160th Electronics Station 1 January – 30 June 1949*, volume 9, 86-87.
[36] "Report of the Subpanel on Aircraft Interception Direction," First Draft, September 19481-5, 18-21, and appendices I and III.
[37] *Ibid*, 19.
[38] Labat T. Fletcher, Cambridge Field Station, "Watson Laboratories Occupancy, Bedford Army Air Base, Mass.," memorandum to the Commanding General, Army Air Forces, through the Commanding Officer, Watson Laboratories, Red Bank, New Jersey, and, the Commanding General, Air Materiel Command, Wright Field, 16 June 1947, appendix I attached to *Unit History of Watson Laboratories Cambridge Field Station 1 April – 30 June 1947.*

---

[39] "2234th USAFR Training Center Hanscom Airport Bedford Telephone Cable Chart," 10 May 1949, and Air Force Cambridge Research Center, "Plan Existing Facilities MEW Hill and Misc. Details," 1953.
[40] Radar Laboratory, Cambridge Field Station, *Technical Progress Report Number Eight to the Steering Committee from the Radar Laboratory*, Cambridge Field Station Report No. E3050, June 1948, 1, in *Unit History of 4135th Air Force Base Unit Cambridge Field Station 1 January – 30 June 1948.*
[41] "Plan Existing Facilities MEW Hill and Misc. Details," 1953; Ruth P. Liebowitz and Paul A. Maria, *A Historical Chronology of Hanscom Air Force Base 1941-1997* (Hanscom Air Force Base: History Office, Electronics Systems Center, November 1997), 5.
[42] *Unit History of 4135th Air Force Base Unit Cambridge Field Station 1 January – 30 June 1948*, attached individual technical progress reports for the laboratories.
[43] Air Materiel Command, *Unit History Cambridge Field Station 3160th Electronics Station 1 July – 31 December 1948*, volume 8, part 1, 36, 50, 85, 136-145.
[44] *Historical Data Cambridge Field Station 3160th Electronics Station 1 January – 30 June 1949*, volume 9, 82.
[45] *Ibid*, 114-115, 120-122.
[46] *Ibid*, 136-138.
[47] Air Materiel Command, *Historical Data Air Force Cambridge Research Laboratories 3160th Electronics Group 1 July – 31 December 1949*, volume 10, 10, 20.
[48] Air Materiel Command, *Cambridge Research Laboratories Historical Data 1 January – 30 June 1950*, volume 11, 7-8.
[49] *Historical Data Air Force Cambridge Research Laboratories 3160th Electronics Group 1 July – 31 December 1949*, volume 10, 23-56.
[50] *Cambridge Research Laboratories Historical Data 1 January – 30 June 1950*, volume 11, 5-26.
[51] Mueller, *Active Air Force Bases*, 1989, 222.
[52] Air Materiel Command, *Cambridge Research Laboratories 3160th Electronics Group Historical Data 1 July – 31 December 1950*, volume 12, part 1, 7-9.
[53] *Ibid*, 58-60, 65-66.
[54] John F. Jacobs, "SAGE Overview," *Annals of the History of Computing* 5, 4 (October 1983): 323-329.
[55] Air Research and Development Command, *History of USAF Cambridge Research Laboratories 1 January – 1 April 1951*, volume 13, part 1, 21. (Mueller gives an official date of December 1952 for the name change in *Air Force Bases*, but primary sources suggest that this is an error.)
[56] *Ibid*, 22.
[57] Karen J. Weitze, *Cold War Infrastructure for Air Defense: The Fighter and Command Missions* (San Diego: KEA Environmental, Inc., for Air Combat Command, November 1999), 90-91.
[58] *History of USAF Cambridge Research Laboratories 1 January – 1 April 1951*, volume 13, part 1, 47.
[59] Air Research and Development Command, *History of the Air Force Cambridge Research Center 1 April – 30 June 1951*, volume 14, part 1, 60.
[60] Air Research and Development Command, *History of the Air Force Cambridge Research Center 1 July – 31 December 1951*, volume 15, part 1, 24-25.
[61] *Ibid*, 26.
[62] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 41.
[63] Air Research and Development Command, *History of the Air Force Cambridge Research Center 1 January – 30 June 1952*, volume 16, part 1, 60 and 65; Mueller, *Active Air Force Bases*, 1989, 225.
[64] Stran Steel, "Thermo-Radiation Bldg Katahdin Hill," 1 November 1954. Site plan with all Katahdin Hill building footprints is included.
[65] LEC Environmental Consultants, Inc., "Cultural Resources," Comprehensive Ecological Analysis Hanscom Air Force Base (Cambridge, Massachusetts: The Boston Partnership, Inc., for Air Force Materiel Command, December 1995, revised August 1997), Massachusetts Historical Commission inventory sheets for the Lincoln Laboratory. On mapping within this discussion, Building 1301 appears as 1302K. Building 1301 is included in the real property printout for the laboratory complex, but is omitted on current base mapping. Building "1302K" appears to be an alternate real property numbering for Building 1301, and can be so interpreted from the "Master Plan Report L.G. Hanscom Field, Bedford, Mass." completed by The Architects Collaborative in ca.1959-1960 (see Volume I, Part III).
[66] *History of the Air Force Cambridge Research Center 1 January – 30 June 1952*, volume 16, part 1, 65-66.
[67] Air Research and Development Command, *History of the Air Force Cambridge Research Center 1 July – 31 December 1952*, volume 17, part 1, 88-89.

[68] Air Research and Development Command, *History of the Air Force Cambridge Research Center 1 January – 30 June 1953*, volume 18, part 1, 257-260.
[69] *History of the Air Force Cambridge Research Center 1 July – 31 December 1952*, volume 17, part 1, 90.
[70] Air Research and Development Command, *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 2, 120. MULDAR may reference some variation on Multiple Digital Computers and Radar Sets, but the author has not been able to find confirmation.
[71] Liebowitz and Maria, *A Historical Chronology of Hanscom Air Force Base 1941-1997*, 1997, 5.
[72] Butler Manufacturing Company, "Office Buildings for the RAND Corporation Laurence G. Hanscom AFB," 20 August 1956.
[73] Air Force Systems Command, "Natural Obstructions RCS: SYS-DEE(A)7201 Hanscom Field," 1 January 1960, revised to 1 February 1973. The building number for the Butler laboratory cluster was 1223 (one number for the group).
[74] Air Defense Command, *4620th Air Defense Wing (Experimental SAGE) 1 June 1955 – 30 June 1958.*
[75] *History of the Air Force Cambridge Research Center 1 July – 31 December 1952*, volume 17, part 1, 91-94.
[76] Air Research and Development Command, *Historical Data Rome Air Development Center 1 July – 31 December 1952*, volume 2, 41-42.
[77] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 91.
[78] The AN/FPS-3 was a fixed (F) radar (P) used for detection (S).
[79] Mueller, *Active Air Force Bases*, 1989, 222.
[80] Jacobs, "SAGE Overview," *Annals of the History of Computing*, October 1983, 328.
[81] Eva C. Freeman (ed.), *MIT Lincoln Laboratory: Technology in the National Interest* (Lexington, Massachusetts: Lincoln Laboratory, Massachusetts Institute of Technology, 1995), 15-33. Discussions and their supporting facts differ slightly from those for the same historic events presented in Robert Wieser's and John Jacobs' articles for the SAGE issue of the *Annals of the History of Computing* of 1983. In particular, timelines are at odds for 1953 and 1954. The work at Hanscom Field is assumed to have involved MIT's Instrumentation Laboratory in the Draper Hangar, and may have also included continued efforts in Hangar A (where MIT installed data link equipment in 1951). The Air Force would move Hangar A to a new flightline location in 1958, and by late 1954 major construction for the FIS alert infrastructure was underway nearby. The command to execute the automatic interception for the MIT B-26 exercise should have originated from the Experimental Control Building (as the mock ADCC), Building 1301. The Experimental SAGE Building (1302F) was not yet in design.
[82] C. Robert Wieser, "The Cape Cod System," *Annals of the History of Computing* 5, 4 (October 1983): 362-369; Air Force Systems Command, "Air Defense Laboratory," drawing 35-06-06, 9 March 1954. The drawings for the Experimental SAGE Direction Center are not originals. They are copies from sometime after 1961.
[83] Carl Koch & Associates, "Air Force Cambridge Research Center Fighter Facilities," 9 February 1952.
[84] Building 1840 is currently not in Air Force ownership, but is of standard Strobel & Salzman type. For the other ADC buildings, drawings held in the civil engineering vault at Hanscom Air Force Base verify the typical FIS pattern, as well as the role filled by Building 1302F. See: Edwin T. Steffian, "Readiness Building," drawing 30-11-01, May 1954; Anderson-Nichols & Company, "Rocket Storage, Checkout and Assembly Building (Unit A)," drawing 33-39-02, May 1954; and, Strobel & Salzman, "Hangar, Maintenance with Shops," drawing 39-01-41, 4 June 1953, modified for Hanscom Field December 1955. The Unit A structure is a standardized design of Weiskopf & Pickworth of New York, and is adapted by Anderson-Nichols for Hanscom.
[85] *4620th Air Defense Wing (Experimental SAGE) 1 June 1955 – 30 June 1958*, 10-11.
[86] Jacobs, "SAGE Overview," *Annals of the History of Computing*, October 1983, 329; Freeman, *MIT Lincoln Laboratory*, 1995, 23.
[87] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 92.
[88] Air Defense Command and Lincoln Laboratory, *Operational Plan Semiautomatic Ground Environment System for Air Defense (Formerly Designated the Transition System)*, 7 March 1955, 107.
[89] The author's collection of drawings for SAGE does not contain any with fully readable original title blocks. The best example to date is that from Minot Air Force Base. Headquarters Air Materiel Command, with Western Electric Co., Inc., and, Burns & Roe, Inc., "SAGE ADES Project Ops-C Building and Ops-D Building," drawing number and original date unclear.
[90] Air Defense Command and Lincoln Laboratory, *Operational Plan Semiautomatic Ground Environment*, 7 March 1955, 86.
[91] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 97.

[92] The Mitre Corporation was an MIT nonprofit spinoff to provide systems engineering expertise for SAGE, set up in 1958 and patterned after RAND. Liebowitz and Maria, *A Historical Chronology of Hanscom Air Force Base 1941-1997*, 1997, 6.
[93] *History of the Air Force Cambridge Research Center 1 January – 30 June 1952*, volume 16, part 1, 64.
[94] Carl Koch & Associates, "Air Force Cambridge Research Center Fighter Facilities," 9 February 1952.
[95] Kuljian Corporation, "Hangar – Maintenance Double-Cantilever Medium Bomber A/C," drawing 39-01-44, original date of 10 December 1951, modified for Hanscom Field September 1953.
[96] Edwin T. Steffian, "Air Force Reserve Training Center (AFRTC) Hangar A/C Maintenance & Operations," drawing 39-04-01, adapted from drawings by Cranshaw, Beardsley & King for identical facilities at Niagara Falls Air Force Base, New York, 11 May 1953.
[97] Air Research and Development Command, "Airfield Pavement L. G. Hanscom Field," September 1956; and, Directorate of Installations, "Laurence G. Hanscom Field, Massachusetts," 1 October 1957.
[98] Richard H. Curtis, Deputy Chief of Staff, Materiel, Air Force Cambridge Research Center, to the Commander, Air Research and Development Command, Baltimore, "Clearance Criteria for Double Cantilever Hangar," memorandum of 4 August 1954, in Record Group 341, Entry 494, Box 494, File "Hangars 1954," National Archives II, Maryland.
[99] "Bedford Airdrome Drainage System," 18 September 1945; and, Liebowitz and Maria, *A Historical Chronology of Hanscom Air Force Base 1941-1997*, 1997, 5.
[100] United States Army Corps of Engineers, New England District, "Laurence G. Hanscom Field A/N Service Club NCO Club and Gymnasium Project Plan," May 1955.
[101] Directorate of Installations, "Laurence G. Hanscom Field, Massachusetts," 1 October 1957.
[102] "New England's Biggest Moving Job," *Boston Globe*, 1 January 1958.
[103] "Airfield Pavement L. G. Hanscom Field," September 1956.
[104] Untitled base plan of ca.1955.
[105] Stran Steel, "Thermal Radiation Bldg.," 1 November 1954; Air Force Cambridge Research Center, "Transmitter & Receiver Bld'gs," drawing 38-12-02, 21 February 1955; Joseph L. Paley, "T.A.C. Building," drawing AW 86-16-01, 30 September 1955; Congdon, Gurney & Towle Inc., "Propagation Studies Bldg.," drawing 32-11-01, ca.1955, first revision date of 7 September 1955; and, Congdon, Gurney & Towle, "Heavy Radar Assembly Bldg.," drawing 35-61-01, undated.
[106] As of 1956, buildings for the geophysics area—although designed by a sequence of local architects and engineers—return to the serial Air Force numbering for the laboratory drawings initiated with the Lincoln Laboratory in October 1951. The superimposition of this particular Air Force system suggests that the overall "laboratory" series was one serving as a standard for the agency, although the repetition of possible multiples at other military installations is not researched here. The drawing series was that of 35-06-xx, with the final digits beginning at "01" for the Lincoln Laboratory Building 1302B. Typically, the final digits indicate an evolution in a building type for the Air Force, with lower numbering representative of an earlier design. Not known is whether or not a single architectural-engineering firm had a contract for "science laboratories" of generic types, or whether each iteration represents a new effort. Between the autumn of 1951 (for the Lincoln Laboratory Building 1302B) and five years later, final digits climbed from 01 to 24.
[107]Anderson-Nichols & Company, "Electronic Radio-Chemistry Laboratory," drawing AW 35-06-24, August 1956, and, Congdon, Gurney & Towle, Inc., "Electronics Laboratory Airborne Facility," drawing AW 35-06-35, 24 December 1957.
[108] Mueller, *Active Air Force Bases*, 1989, 222-224.
[109] Sumner Sollitt Company, with Frederick Stanton, "A Positive Ion Accelerator & Gamma Source Hot Cell," 17 July 1959; Hoyle, Doran & Berry, "Plasma Physics Laboratory," drawing AW 35-06-48, June 1961; A. L. Delaney & Associates, "Linear Accelerator Laboratory," drawing AW 35-06-53, November 1961; and, Anderson-Nichols & Co., Inc., "Radiation Physics Laboratory," drawing AW 35-06-55, February 1962.
[110] Air Force Cambridge Research Center, "Rawinsonde Bldg.," drawing 35-50-01, 9 June 1953; Congdon, Gurney & Towle, Inc., "Atmospheric Thermal Radiation Field Test Facilities," drawing 35-06-21, May 1956; Congdon, Gurney & Towle, Inc., "Electro Magnetic Bldg.," drawing 35-06-26, August 1957; and, Stewart Associates, Inc., "Geo-Physics Science Laboratory," drawing 35-06-31, May 1957.
[111] Samuel Glaser Associates, "Data Analysis Lab (FY-59)," drawing 35-06-42, October 1958.
[112] Air Force Electronics Systems Division, "Seismic, Gravity Pier, Facility," drawing 35-06-11, 28 January 1967. Drawing number, 35-06-11, indicates that the original date of the building is about 1952. Exterior appearance also supports an early 1950s construction date.

[113] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 59-62.
[114] The Raytheon hangar is not Air Force property.
[115] Royal C. Flanders, "Cantilever Hangar Design," *The Military Engineer* 51, 342 (July-August 1959): 284-286.
[116] Burns & McDonnell, "Maintenance Dock, Large A/C (CONAC)," drawing 39-05-16, 20 April 1964.
[117] Liebowitz and Maria, *A Historical Chronology of Hanscom Air Force Base 1941-1997*, 1997, 5-9.
[118] E. Michael Del Papa, *A Historical Chronology of the Electronic Systems Division 1947-1990* (Hanscom Air Force Base: History Office, Electronic Systems Division, October 1991), *passim*; and, Ruth P. Liebowitz, *The Electronic Systems Center 1991- 1996 An Overview History* (Hanscom Air Force Base: History Office, Electronic Systems Center, April 1999), 1-32.
[119] Mueller, *Active Air Force Bases*, 1989, 222-224.
[120] Del Papa, *A Historical Chronology of the Electronic Systems Division 1947-1990*, 1991; and, Liebowitz, *The Electronic Systems Center 1991- 1996*, 1999: *passim*.
[121] Mueller, *Active Air Force Bases*, 1989, 222-224.
[122] Ruth P. Liebowitz, *Air Force Geophysics: Contributions to Defense and to the Nation, 1945-1995*, PL-TR-97-2034, Special Report No. 280 (Hanscom Air Force Base: Geophysics Directorate, 8 April 1997), 17, *passim*.
[123] "Huge New Hangar at Kansas City Airport Outstanding Example of High-Strength Cable Suspended Roof," *Civil Engineering* 27, 9 (September 1957): 127.
[124] Company history and highlights of major commissions are posted at www.burnsmcd.com.
[125] "Professional Records of Nominees," *Civil Engineering* 11, 12 (December 1941): 735.
[126] Harold E. Wessman, "Steel-Arch Hangar Tested to Destruction," *Engineering News-Record* 139, 16 (16 October 1947): 105-109.
[127] "Partner Runs Firm as Strobel Runs PES," *Engineering News-Record* 153, 5 (29 July 1954): 76.
[128] C. Pratt Brown, Brigadier General, Acting Assistant Chief of Staff, Installations, "Mitchell Mobilhangar," undated memorandum of 1954, in Record Group 341, Entry 494, Box 494, File "Hangars 1954," National Archives II, Maryland.
[129] Mitchell Mobilhangar Corporation, letter to John Ferry, Special Assistant, Air Installations, United States Air Force, 12 May 1954, in *ibid.*
[130] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 29-34.

Chapter 6: Hill Air Force Base

Historic Missions of the Cold War

Hill Air Force Base functioned as an Air Materiel Command / Air Force Logistics Command (AFLC) depot installation during the Cold War, with missions concentrated on aircraft modification, management and associated assignments for selected guided and intercontinental ballistic missiles (ICBMs), and logistical supply functions for the Ogden Air Materiel Area (OOAMA)—the latter strongly oriented toward air munitions.[1] First named the Ogden Air Depot and sited adjacent to the existing Ogden Ordnance Depot of the early 1920s, the base became Hill Field in December 1939. The installation was operational for the Rocky Mountain region in 1940. The Ogden Air Depot featured the standard configuration of four repair hangars and shops, with a double Air Transport Squadron hangar, multiple engine test cells, warehouses, and support structures. During World War II, personnel winterized aircraft for Alaska, modified B (bomber) -17s, repaired R-2800-R engines, overhauled B-24s, and carried out the depot's supply functions. During the earliest Cold War years, Hill Field had an uncertain future due to its obsolete, inadequate facilities and questionable capability to take on new Army Air Forces missions. Hill Field became Hill Air Force Base in January 1948 in honor of Major Ployer Peter Hill, an early military test pilot. The base managed the OOAMA for Air Materiel Command. Personnel at the installation prepared excess World War II aircraft for outside storage at the base; overhauled B-26s, B-29s, and C (cargo) -82s for duty in the Korean War theater; and, continued the general supply mission. Primarily preoccupied with Korea, Hill sustained no duties associated with the new B-36, atomic weapons, jet fighter aircraft, or early guided missiles until 1952. In that year, Air Materiel Command made Hill the prime depot for Northrop aircraft parts. The same year, Hill became the prime depot for the B-62 pilotless aircraft, forerunner for the Snark guided missile. As of 1953, personnel at Hill began modifying the F (fighter) –89.

After upgrading to a 13,500-foot runway and adding several state-of-the-art facilities during 1955-1957, Hill steadily shifted into maintenance and modification assignments for key jet fighter aircraft and missiles. At mid-decade, supply functions at the base also increased. The OOAMA at Hill undertook the resupply of Alaska's Aircraft Control & Warning (AC&W) sites and support of Alaskan Air Command. In April 1955, Hill nearly doubled in size as it annexed the neighboring Ogden Arsenal, subsequently known as the West Area Complex, to store, maintain, and test its own ordnance. Air munitions handled at Hill included the MB (missile bomber) -1 Genie, a nuclear-tipped air defense missile carried by the F-89J, F-101B, F-102, and F-106; biological and chemical weapons; and later, the Minuteman I, II, and III, Titan II, and MX (missile experiment) / Peacekeeper ICBMs. Simultaneously, Hill received four jet engine overhaul assignments. By late in the decade, personnel at Hill sustained missions for F-101, two X (experimental) -series research vehicles, selected target drones, and the Bomarc (Boeing Michigan Aeronautical Research Center) guided missile.

The major shift toward an accelerated Cold War agenda at Hill Air Force Base came during the very late 1950s and is tied to the Bomarc and Minuteman missions. As of spring 1957, Air Materiel Command assigned the Ogden Air Materiel Area (AMA) prime maintenance and supply responsibilities for the Marquardt Aircraft Company and Aerojet-General Corporation. Marquardt built assembly and test facilities at nearby Little Mountain, Utah, to manufacture ramjet engines for Bomarc, dedicating the facility in late 1959. Also nearby were Air Force Plants (AFPs) 78 (Thiokol) and 81 (Hercules). In January 1959, the installation acquired major tasking for the Minutemen ICBM, with multiple associated missions for the missile continuing past the Cold War period. The Thiokol Chemical Company, Hercules Powder Company, and Aerojet-General would all work on the three stages of the Minuteman motor. Boeing Aircraft and the Air Force also built AFP 77 on Hill Air Force Base to assemble the Minuteman. At the outset of the next decade, Hill additionally

controlled considerable range lands. One of the ranges, the Hill Air Force Range (formerly, the Newfoundland Mountain Air Force Range), would evolve into a portion of today's Utah Test and Training Range (UTTR) and would support important Minuteman and MX / Peacekeeper missions, as well as Air Force Weapons Laboratory (AFWL) testing of hardened aircraft shelters and revetments, between 1966 and the middle 1980s.

While the ICBM mission at Hill continued to dominate depot functions at the installation late in the Cold War, the base moved forward with two more major fighter overhaul and modification missions for the F-4 and the F-16. As of the late 1970s, the 388th Tactical Fighter Wing also established a multinational training program for F-16 support teams from the United States, Belgium, the Netherlands, Denmark, and Norway. Hill acquired the short-range attack missile (SRAM) mission in the 1970s, simultaneous with Boeing's assembly of the SRAM in AFP 77. As of the middle 1980s, the base additionally supported the air-launched cruise missile (ALCM). The SRAM and ALCM were weapons systems vital for Strategic Air Command (SAC) and were fitted to B-52s, and later, B-1s. The missiles replaced the Hound Dog / Quail weapons system of the 1960s. Throughout the Cold War, Hill periodically sustained a SAC tenant mission, including rail-mobile basing tests for the Minuteman I of the early 1960s (Project Big Star) and satellite alert of the middle 1970s. Military Airlift Command (MAC) also established a short-lived helicopter pilot training program at the base during the Vietnam War.

Primary Missions

Functioning primarily as the OOAMA during the Cold War, Hill Air Force Base supported key missions of Air Materiel Command / AFLC that included:

- preparation and permanent storage of large numbers of pursuit, bomber, and trainer aircraft, aircraft engines, and vehicles, post-World War II;
- reclamation, disposal, and sale of aircraft parts;
- aircraft repair and modification for the B-17, B-26, B-57, C-45, C-47, C-54, C-82, C-119, C-124, C-125, F-47, F-51, F-61, F-82, F-4, F-16, as well as various trainer and L (liaison) aircraft;
- aircraft engine maintenance;
- specialized supply and support responsibilities;
- repair and modification of B-26, B-29, and C-82 aircraft for the Korean War;
- extensive assignments supporting the F-84;
- prime management for the F-89 and F-101 jet fighters;
- major maintenance and modification for the F-102;
- landing gear overhaul for multiple aircraft after 1970;
- responsibility for Project Mona Lisa, the resupply of AC&W sites in Alaska;
- management of selected guided missiles, including Snark, Bomarc, Crossbow, and Bull Goose;
- developmental management of the Skybolt air-launched ballistic missile;
- refurbishment, modification, and repair of the SRAM and ALCM;
- support of the target drone program, and subsequently, testing of remotely piloted test vehicles (RTVs);
- prime maintenance and components support for the XC (experimental cargo) -1 and the X-3;
- prime maintenance for selected rocket and ramjet engines;
- development and maintenance of a capability to store, handle, transport, escort, inspect, renovate, and dispose of Air Force munitions, excluding nuclear munitions (before 1960), but including biological and chemical weapons;

- prime maintenance management for the MB-1 Genie;
- air munitions testing, including drop tests, x-raying, vibration, jolt and jumble tests, pressured, temperature- and humidity-sensitive tests, shatter and blast tests, acceleration tests, temperature, humidity and aging tests, salt corrosion tests, and simulation of actual storage and flight conditions;
- Logistics System Program Manager for ICBMs (taken over from the San Bernardino AMA at Norton Air Force Base in Southern California), with prime management and specialized responsibilities for Minuteman and MX / Peacekeeper, and acquisition of Titan II;
- support of Athena test launches from the Green River, Utah, complex to the White Sands Proving Ground (Missile Range) in New Mexico;
- storage of excess Minuteman and Titan II ICBMs;
- range support for the testing of hardened aircraft shelters and revetments;
- air munitions shipments during the Vietnam War;
- testing of SAC's Airborne Launch Control System (ALCS);
- flash x-ray testing for missiles in simulated flight at the Little Mountain Test Annex; and,
- program management and engineering responsibilities for the Maverick.

Tenant Organization Missions

The notable tenant missions at Hill during the Cold War included those of SAC, MAC, and Tactical Air Command (TAC):

- Project Big Star, SAC's rail-mobile deployment for Minuteman I;
- SAC satellite alert;
- MAC helicopter flight testing and pilot training;
- assignment of TAC fighter wings and squadrons; and,
- multinational training for the maintenance and operation of the F-16.

Chronology

The Ogden Air Depot was one of six installations directly created through the Wilcox Bill of 1935. (The Air Corps established a seventh, the Hawaii Air Depot, through expansions at Hickam Field.) The legislation, sometimes known as the Wilcox-Wilson Bill (Public Law 263), included three permanent depots in the West, the Rocky Mountain region, and the South, as well as a territorial depot in Hawaii. These first Wilcox Bill depots evolved as the Sacramento Air Depot (McClellan Air Force Base in California), Ogden Air Depot (Hill Air Force Base), and Mobile Air Depot (Brookley Air Force Base in Alabama). Site selection, land acquisition, and construction moved at differing paces, with other depots added during World War II. While the Army dedicated the Sacramento Air Depot in spring 1939, the Ogden facility had a beneficial occupancy date of April 1941.[2] The basic infrastructure for air depots of 1938-1943 typically included a composite of two standard flightline hangars: the Airplane Repair Building (Building 225) and the Air Transport Squadron Hangar (Building 270). The Army also erected warehousing and engine test cells (Buildings 267 and 268) to support maintenance and overhaul operations. The Airplane Repair Building was a tied steel arch hangar of 275-foot span, 190 to 250 feet deep. The hangar often had attached shops and was a key transitional structure for large aircraft modification during the first years of the Cold War. Designed and engineered through the Army Quartermaster Corps, the Airplane Repair Building anticipated the size of the B-29. Engineers planned for the structure to accommodate even larger bombers, but were only marginally prepared for the extreme size and height of the B-36. The appearance of the Airplane Repair Building at the individual depot bases varied. In some instances, the Army did not erect the

hangar. In others, the service arm built a single hangar (Kelly Field in Texas) or a pair of hangars (Hickam Field in Hawaii) (see Volume II, Chapter 7). In yet another variation, the Materiel Division of the Air Corps placed three hangars with rear shops side by side (at McClellan) (see Volume II, Chapter 10) or near each other (at Wright Field in Ohio) (see Volume II, Chapter 14). The standard configuration, however, became two pair of hangars with a complex of shops in the center of the cluster, as at the Ogden Air Depot (Building 225).

The Air Corps did not commission the second hangar of the depot couplet—the Air Transport Squadron Hangar—until 1940. The basic Air Transport Squadron Hangar was the work of Detroit architect Albert Kahn. The Air Corps (or subsequently, Army Air Forces) erected the hangar over a period of years, in some instances with important modifications. The Air Transport Squadron Hangar appeared in both single and doubled versions. When doubled, the hangar had technically evolved into the Operations - Transport Squadron and Flight Test Hangar. Fred N. Severud, an internationally prominent engineer, modified Kahn's Air Transport Squadron Hangar to create this structure. Hill, however, received an unmodified Air Transport Squadron Hangar (Building 270), with construction underway as of mid-1943[3] (Plate 75). (The Air Corps erected a half-hangar at Hickam Field and Operations - Transport Squadron and Flight Test Hangar pairs at Griffiss, Kelly, Tinker, Robins, and Patterson Fields. The Air Corps did not erect the hangar in any form at McClellan. [See Volume II, Chapters 7, 10, 11, 12, 13, and 14.]) During World War II, the Air Corps also experienced two phases of air base expansion, known as the 54-Group Plan of late 1940 and the 84-Group Plan of spring 1941. The Corps' depots in Oklahoma City; Rome, New York; and, near Macon, Georgia, were a part of the 54-Group Plan for example, while depots in Spokane, Washington, and San Bernardino, California, derived from the 84-Group Plan. The Army Air Forces frequently implemented the 84-Group Plan with less standardization than had the Air Corps in its buildout for the 54-Group Plan. The Army Air Forces omitted the Air Transport Squadron hangar altogether for Spokane (Fairchild Air Force Base in Washington), and advanced to an even later redesign of the Operations - Transport Squadron and Flight Test Hangar at Eglin Air Force Base in Florida and at two California installations—Norton and Travis Air Force Bases (see Volume II, Chapter 4). Only Norton was also a depot base (for the San Bernardino Air Materiel Area [AMA]). This final iteration of Kahn's Air Transport Squadron Hangar was the continued work of engineer Severud and formally known as the Hangar (Expansible) for V.H.B. [very heavy bomber] Aircraft. The V.H.B. hangar dated to 1944-1945 and referenced planning for the B-36.[4]

The Air Corps' choice of Ogden for its Rocky Mountain depot was partially contingent on the existence of the Ogden Ordnance Depot. The Army had selected Ogden immediately after World War I primarily due to the geographic and climatic conditions of the region. The site featured porous sand, level topography, low humidity, and a 5,000-foot elevation, all excellent conditions for ammunition storage. These conditions would be equally appropriate for ICBM storage and testing during the Cold War. Initial building activity for what was first named the Ogden Arsenal concentrated in the early 1920s, with the installation only in modest use at the end of the decade. After a major windstorm of 1929, the Army neglected the arsenal until a second major building campaign of 1935-1939. Expansion of the arsenal as the Ogden Ordnance Depot was a byproduct of preparations for World War II, and focused on multiple magazines, warehouses, and a bomb and artillery shell assembly plant.[5] Four runways, each 7,500 feet long and 150 feet wide, also used land within the arsenal. Planning surveys and land acquisition for the air depot consumed 1938-1939, with erection of runways, buildings, and structures occupying much of 1940-1943. Construction for the four-hangar Airplane Repair Building was still in progress during 1943, with two jet engine test cell facilities erected during 1941-1942 (12 cells total).[6] Major overhaul work at the base did not begin until 1942, with winterization of B-26s, P (pursuit) -39s, and P-40s for the Alaskan war theater. Modification and rehabilitation projects for the B-17 and B-24, as well as aircraft engine overhaul,

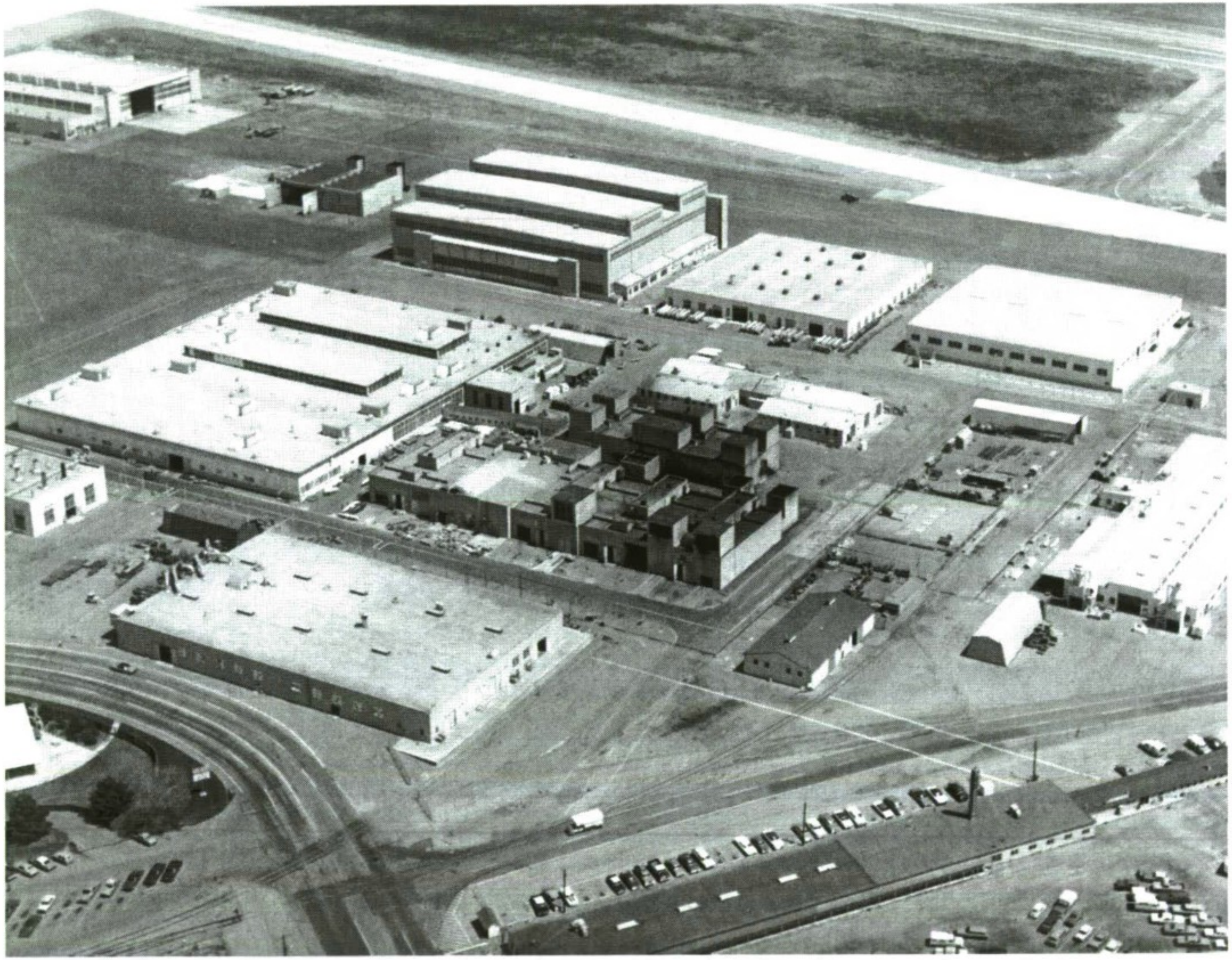

Plate 75: Aerial view of Hill Air Force Base, undated. Building 270: Albert Kahn, Air Transport Squadron Hangar, 1940-1943, background middle. Building 222: Sverdrup & Parcel, Run-Up Facility (Hush House), 1964, left of Building 270. Building 220: Roberts & Schaefer, Painting and Cleaning Hangar, 1952-1953, background left edge. Buildings 267-268: J. Gordon Turnbull, Engine Test Cells, 1940-1941, center. Southwest Research Center, Thor shelter, middleground right. (See also, Plates 77 and 91.) Courtesy of the History Office, Hill Air Force Base.

followed from mid-1942 to 1944. By spring 1944, the Army Air Forces was already evaluating the Ogden depot for post-war storage of excess and surplus aircraft. The first planes arrived for storage in June. As World War II ended in 1945, the Ogden Air Depot completed a rehabilitation project for the P-47 and prepared stored B-24s for removal to Kingman, Arizona. Base personnel also initiated reclamation of aircraft parts. Beginning in July, the Army Air Forces sent over 600 bombers and 100 pursuit aircraft to Ogden for outdoor storage.[7]

As depot operations at Ogden moved forward into the Cold War period, the installation's AMA boundaries enlarged to include portions formerly within the Spokane AMA managed by Spokane (later, Fairchild) Air Force Base in Washington. The increased geographic jurisdiction was part of an overall shrinking of Air Materiel Command depots in the late 1940s. Ogden continued to store aircraft and also received excess Army vehicles previously going to Spokane. Primary tasking at the depot focused on preparation of aircraft for both outdoor and indoor storage at the installation. Ogden had 750 vehicles from Spokane in mid-1947 and over 1,200 aircraft by the end of the year. Base personnel also disposed of excess equipment and materiel as a part of their operations. Hill Field became Hill Air Force Base in mid-January 1948, sustaining its responsibilities for the Ogden AMA. Activities concentrated on logistics and basic supply, with no significant aircraft or engine overhaul assignments (outside those preparatory to storage) until 1949. At mid-year, engine repair returned to the installation. The major mission at Hill continued to be aircraft storage. (As late as mid-1955, 693 aircraft remained in an outdoor storage area at Hill.)[8] As was the case for several depots within Air Materiel Command, Ogden participated in important supply airlifts of the period, including to Soviet-blockaded Berlin. At the close of 1949, however, Ogden's personnel were severely cut back amidst talks of depot phaseout or closure.[9] The Korean War changed the declining operational situation at Hill Air Force Base. To support the war effort, Air Materiel Command assigned Ogden significant logistical duties as well as the repair and modification of multiple aircraft. Overhaul and preparation tasks focused on the B-26 and B-29. Although the installation had requested a new runway in the 1946-1947 fiscal year budget, cutbacks had eliminated that improvement—a factor in the depot's lessening status within the command. Ogden did make some emergency changes to its runways, nonetheless, and lengthened the north / south runway to 10,000 feet through graded and graveled extensions of 1,300 and 1,200 feet at each end in 1950. Base engineers topped at least one of the extensions with asphalt in 1951.[10] While the depot had no plans for maintenance or overhaul of the B-36, its improved runway was able to land the experimental cargo version of the very heavy bomber—the XC-99. In mid-October 1950, the XC-99 delivered 100,000 pounds of supplies to the base. Stationed permanently at Kelly in San Antonio, the XC-99 flew weekly to McClellan in California, and at least once to Hill. Only one XC-99 was ever built.[11]

While the Korean War was in progress, Hill began positioning itself for a long-term Cold War workload. On paper, the earliest missions acquired were for jet fighter aircraft and guided missiles. New assignments necessitated upgrading and expanding installation infrastructure, from runways to buildings. In the late 1940s, the depot had requested a 10,000- by 200-foot northwest / southeast runway in anticipation of the era ahead. By fiscal year (FY) 1951, Hill increased its desired runway specifications to 10,000 by 300 feet. Matters still stalled, and Air Materiel Command advised Hill to beef up its existing runways as needed. By early 1952, base engineers argued for a 13,500-foot facility with provisions for extension to 15,000 feet. They sought a runway capable of handling an expanded overhaul mission for any plane in the Air Force. Hill continued to pressure Headquarters Air Materiel Command for a modern runway. The base commander noted in March 1953 that the "runway will make the difference as to whether we...are an adequate operator with a potential future, or just another Middletown." The Middletown depot near Harrisburg, Pennsylvania, at Olmsted Air Force Base did indeed close very early, in 1967. Construction for a 13,500- by 200-foot runway at Hill was not underway until April 1955,[12] with completion in March 1957.[13] Two major buildings added at Hill at this same time included a large warehouse serviced by railroad tracks and a

maintenance painting and cleaning hangar. Both were state-of-the-art facilities that featured innovative, reinforced concrete construction. The warehouse dated back to an Air Materiel Command-wide design of 1951-1952, but was not under construction at Hill until after mid-decade. The special hangar was a design of 1952-1953, in progress at the depot in November 1954.[14] These two buildings were very large and complicated undertakings. Neither was finished until 1957-1958. The warehouse was a 560,000-square foot structure that cost $3,600,000. The paint hangar included 34,000 square feet of interior clearspan space and another 28,000 square feet of attached shops. Its final cost was estimated between $2,250,000 and $2,500,000. The American civil and military engineering press discussed the warehouse in multiple articles, evaluating specific examples of the structure at different Air Materiel Command installations. The journals also made repeated assessments of the painting and cleaning hangar. The warehouse had a somewhat troubled history due to the extreme newness of its technology for the early 1950s (see Volume I, Part II). By the date of its construction at Hill, the warehouse had undergone improvements and represented the mature iteration of the facility. The painting and cleaning hanger, in contrast to the warehouse, was a unique structure built only once. It sustained no problems and its details were much talked about across the international engineering community.

Hill's warehouse was one of a group of single, paired, and tripled Special AMC [Air Materiel Command] Warehouses erected at 20 prime depots, subdepots, and special depots in the continental United States. The warehouse was modular, relying on prefabricated components and cutting-edge construction techniques. Civil engineers in the Air Installations Division of the command contracted the Special AMC Warehouse specifically to automate and streamline the business of supply and logistics. Although other attempts at successful thin-shell, precast panel construction were underway for both the Navy and the Air Force in 1951-1952, these were still very few in number—making the Special AMC Warehouse a truly "new" building (see Volume I, Part II). The Special AMC Warehouse not only represented a civil engineering feat for its time, it also reflected the management philosophies of Air Materiel Command's new commander of 1951, General Edwin W. Rawlings. General Rawlings had a Masters in Business Administration (MBA) from Harvard and was an embodiment of the business-oriented 1950s. A prototypical design for the Special AMC Warehouse first appeared in early 1951 at Tinker Air Force Base for the Oklahoma City AMA (see Volume II, Chapter 13). By spring 1952, the Baltimore architectural-engineering firm of L.P. Kooken finalized the design for the warehouse to include two different rigid framing systems and three variations in wall and roof paneling. Both rigid frames were reinforced concrete, column-and-girder in type, with the distinctions between them essentially ones of reinforcement placement. The framing for the warehouse spaced columns every 67 feet, 2 inches. Wall treatment allowed for choices of fairly traditional masonry (either concrete block or hollow tile), poured-in-place reinforced concrete, or precast, thin-shell reinforced concrete, while roof slab variations were either precast plank or thin-shell, precast ribbed panel. The size of the Special AMC Warehouse ranged from 40,000 square feet (at Topeka, Kansas) to over 1,500,000 square feet (two warehouses side by side at McClellan) (see Volume I, Part II and Volume II, Chapters 7, 10, 11, 12 and 13).

The key innovative feature of the warehouse was the thin-shell wall and roof panel structure. This particular detail was also found most often across the command, although other variations existed. The technology was under sharp, positive discussion in international engineering circles, and derived from the 1930s and 1940s efforts of a handful of leading engineers. Under the leadership of engineer Anton Tedesko, Roberts & Schaefer of Chicago was the earliest firm working with thin-shell technology in the United States. Tedesko, an Austrian engineer, had hired with Roberts & Schaefer specifically to introduce thin-shell construction patented by the German firm Dykerhoff & Widmann (see Volume I, Part II). Roberts & Schaefer also achieved remarkable arch spans in hinged steel. By about 1948, a competitor firm, Ammann & Whitney of New York, was also engineering structures in a thin-shell technique. Nonetheless, in 1951, thin-shell technology was still relatively rare and, with

the exception of tilt-slab house design—such as Irving Gill's work on the West Coast in the early 20th century, thin-shell panel construction was new. L.P. Kooken was known to Air Materiel Command through the firm's design of an armament hangar at Eglin in 1950, and for other reinforced concrete structures in the civilian sector. Immediately after the commissioning of the Special AMC Warehouse, the Air Force also turned to thin-shell concrete frame-and-panel technology for major projects at overseas bases. The Navy used the technology for important warehouse projects as well. The Special AMC Warehouse of 1951-1952 was under construction across Air Materiel Command installations as late as 1958. For the most part, those warehouses built first relied upon an unperfected design and had serious flaws. During 1955-1956, several of the warehouses partially failed structurally. The situation caused the command to bring in Ammann & Whitney to refine L.P. Kooken's design and to devise a retrofitted structural improvement for the existing warehouses. The Special AMC Warehouse erected at Hill was 400 feet wide (a standard dimension for all of the warehouses across the program) and 1,400 feet long. A regional architectural-engineering firm adapted L.P. Kooken and Ammann & Whitney drawings for Hill in May 1955.[15] Construction was underway in mid-July and eight percent complete as of the close of the year.[16] The partial roof collapse of faulty bents in girder sections of the warehouse at Wilkins Air Force Station in Shelby, Ohio, occurred in August 1955, with trouble already also acknowledged at Robins Air Force Base in Georgia (see Volume II, Chapter 11). Ammann & Whitney inspected both sites before the close of the year, proposing formal recommended changes in early 1956. The warehouse at Hill incorporated Ammann & Whitney's design improvements: specific placement of additional stirrups and reinforcing steel across full girder lengths.[17] Workmen finished the Special AMC Warehouse for the Ogden AMA (Building 850) in mid-August 1957. The warehouse was one of the last erected in the program[18] (Plate 76).

The painting and cleaning hangar (Building 220) was the third major infrastructure improvement at Hill in the middle 1950s. The hangar was under construction simultaneously with the runway and the Special AMC Warehouse (Plate 77). Although Air Materiel Command's mission required hangars at the depots to overhaul and refurbish aircraft, the command never developed a standardized painting and cleaning facility during the Cold War. Air Materiel Command improvised such hangars in many instances, often in wide-ranging ways. At depots like that of Tinker (for the Oklahoma City AMA), Air Materiel Command benefited from the presence of an Air Force manufacturing plant for Douglas Aircraft across the World War II flightline. During the late 1940s, the Air Force had annexed the Douglas plant and incorporated its structures into the maintenance and overhaul mission for the Oklahoma City AMA. The ad hoc situation had made it possible for Air Materiel Command to adapt an aircraft manufacturer's painting and cleaning hangar of 1943 to meet Cold War needs in the early 1950s. Designed by the Austin Company, the structure at Tinker featured steel-and-reinforced-concrete framing faced with brick veneer. At other depots, such as McClellan and Warner Robins, an opposite approach prevailed. Without the permanent infrastructure offered through an annexed Air Force aircraft plant, McClellan and Robins Air Force Bases relied on easily erected, prefabricated steel hangars adapted for the painting and cleaning task (see Volume II, Chapters 10 and 11). At Kelly, AFLC (the follow-on to Air Materiel Command) modified its World War II Air Transport Hangar as a paint facility for the C-5 in the early 1970s (see Volume II, Chapter 7). The command decision to commission a state-of-the-art paint hangar at Hill in late 1952 was an altogether unusual step. The decision foreshadowed consistent efforts through the Directorate of Civil Engineering at Headquarters Air Force by the early 1960s to develop a standard painting and cleaning hangar for buildout across Air Materiel Command—although this never occurred. Air Materiel Command did plan a prototype for Robins in 1963, but instead erected a standard-design corrosion control shelter and modified it for painting and cleaning aircraft. Not until 1968, did AFLC achieve a paint hangar that was as advanced as the one at Hill. AFLC built this late 1960s painting and cleaning hangar for the F-111 at McClellan, incorporating state-of-the-air ventilation and environmental controls (see Volume II, Chapters 10 and 11).

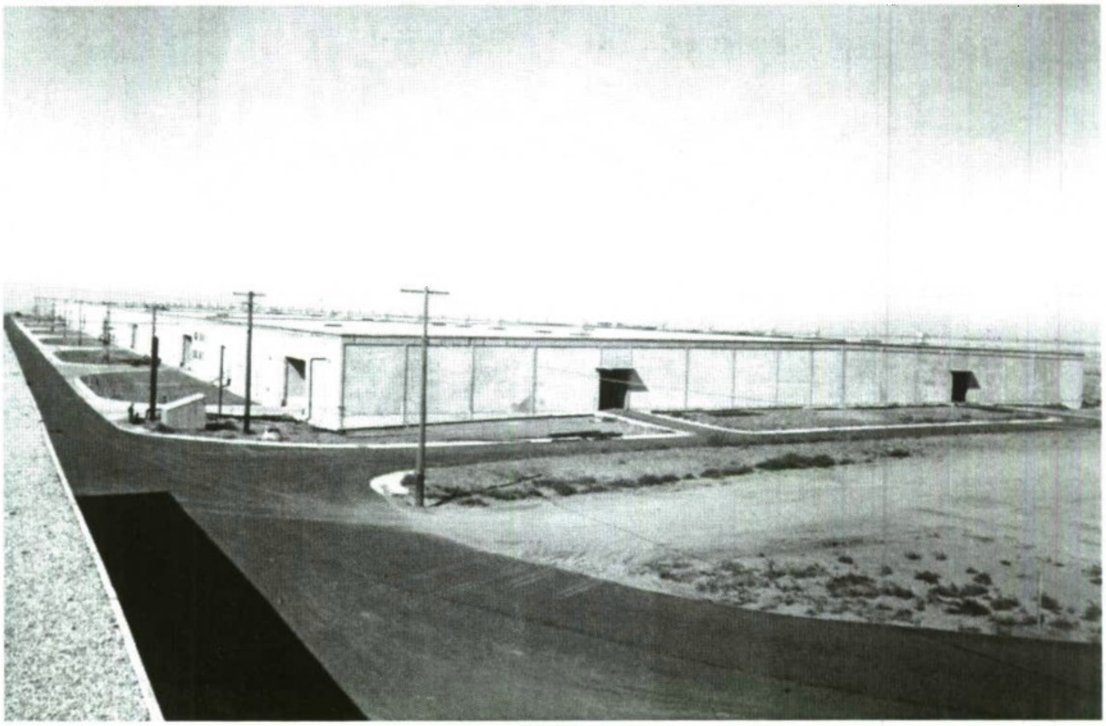

Plate 76: L.P. Kooken and Ammann & Whitney. Special AMC Warehouse (Building 850), Hill Air Force Base. In *History of the Ogden Air Materiel Area 1 July – 31 December 1957.*

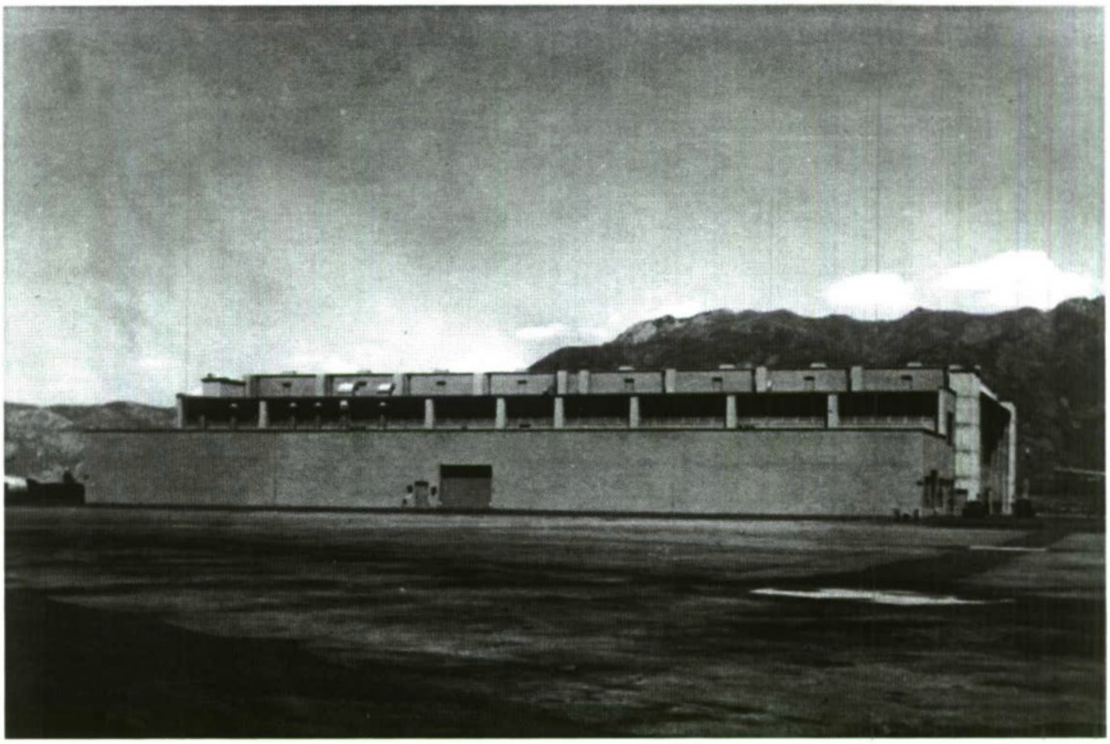

Plate 77: Roberts & Schaefer. Painting and Cleaning Hangar (Building 220), Hill Air Force Base, 1952-1953. Undated view. Courtesy of the History Office, Hill Air Force Base.

The painting and cleaning hangar at Hill was a precast, prestressed concrete structure with a 130-foot clearspan and an overall footprint of 263 by 242 feet.[19] As was the case for other very important Air Force-wide building programs (see Volume I, Part III), efforts toward the achievement of a standardized painting and cleaning hangar involved detailed coordination between the Directorate of Installations (civil engineering) at Headquarters Air Force and the Air Installations Division (civil engineering) at Headquarters Air Materiel Command at Wright-Patterson. After review of reports sent back and forth between Headquarters Air Force and Headquarters Air Materiel Command, the Air Installations Division at Wright-Patterson planned to execute a contract for the hangar at Hill in June 1953. The command hired Roberts & Schaefer of Chicago to design and engineer the specialty structure. The overall cost of the hangar was set at $2,432,000, including engineering. This figure was in addition to $84,670 paid to Roberts & Schaefer for preliminary work on the hangar in late December 1952.[20] Under construction at Hill in late 1954, the structure's precast, prestressed reinforced concrete, rigid-frame high-bay was internationally notable. Design of the hangar also included precast roof panels. Anton Tedesko was the lead engineer for the job, with a young American engineer, David P. Billington, assigned to the project.[21] During 1953-1954, Billington simultaneously served as the engineer for another major Air Force job utilizing the same technology, the building program at Lajes Air Base in the Azores. Anton Tedesko handled many significant civil engineering design problems for the Army, Navy, and Air Force between 1939 and the late 1960s (see Volume I, Part II). David Billington would go on to become a professor of civil engineering at Princeton University, and would write the textbook on thin-shell concrete structures.[22]

Roberts & Schaefer's patented thin-shell technique allowed interchangeability of building components, speed in erection, and lower overall costs. The hangar at Hill featured two interior 130-foot-square spaces with 38-foot clear height for cleaning and painting. Each area was airtight. The painting and cleaning hangar at Hill was the first reinforced concrete, rigid-frame structure using precast, prestressed girders commissioned by the federal government, while the hangar's precast, prestressed members were the longest erected in the United States at the time of their construction. Concrete girders were 136 feet long. Each weighed 84 tons. Thin-shell roof panels measured 29 by 11 feet and weighed six tons apiece. The complete structural system featured reinforced concrete columns, precast, prestressed girders, and thin-shell roof panels. Engineers tied the framing together by casting poured concrete joints between the columns and girders to create a monolithic frame from the roof panels to the building's footings. The composite girder, poured slab band, and roof panel behaved like a large T-beam. Interior walls, between the columns, were reinforced concrete block. The painting and cleaning hangar at Hill also included an unusual ventilation system that relied on a low-velocity duct. This feature determined the shape and structure detailing of the hangar, and made the use of respirators unnecessary by painting personnel.[23] Hill's painting and cleaning hangar was 90 percent finished in June 1956.[24] Delayed by three rough winters, contractors did not complete the hangar until February 1957.[25] Although Hill's hangar was a undisputed success, the long process of its design and erection, as well as its cost, caused Air Materiel Command and AFLC to return to prefabricated hangars for the painting and cleaning task after this one-time effort at Hill. (Of note, the cost for the McClellan hangar was only $1.7 million—14 years later.) The paint hangar completed the major upgradings at Hill in preparation for anticipated aircraft missions as of the later 1950s. In April 1955, Air Materiel Command also took over the neighboring Army arsenal, a facility planned to accommodate both air munitions and missiles missions[26] (Plate 78).

As part of a major Air Materiel Command reorganization of its depots and their jurisdictions (see Volume I, Part II), the Ogden AMA acquired workloads associated with particular aircraft manufacturers in 1952. Simultaneously, the AMA continued to sustain responsibility for each of the Air Force and Air National Guard bases within its geographic boundaries (see Volume I, Part II). In 1954, Ogden also assumed logistics support for all bases and activities under Alaskan Air Command,

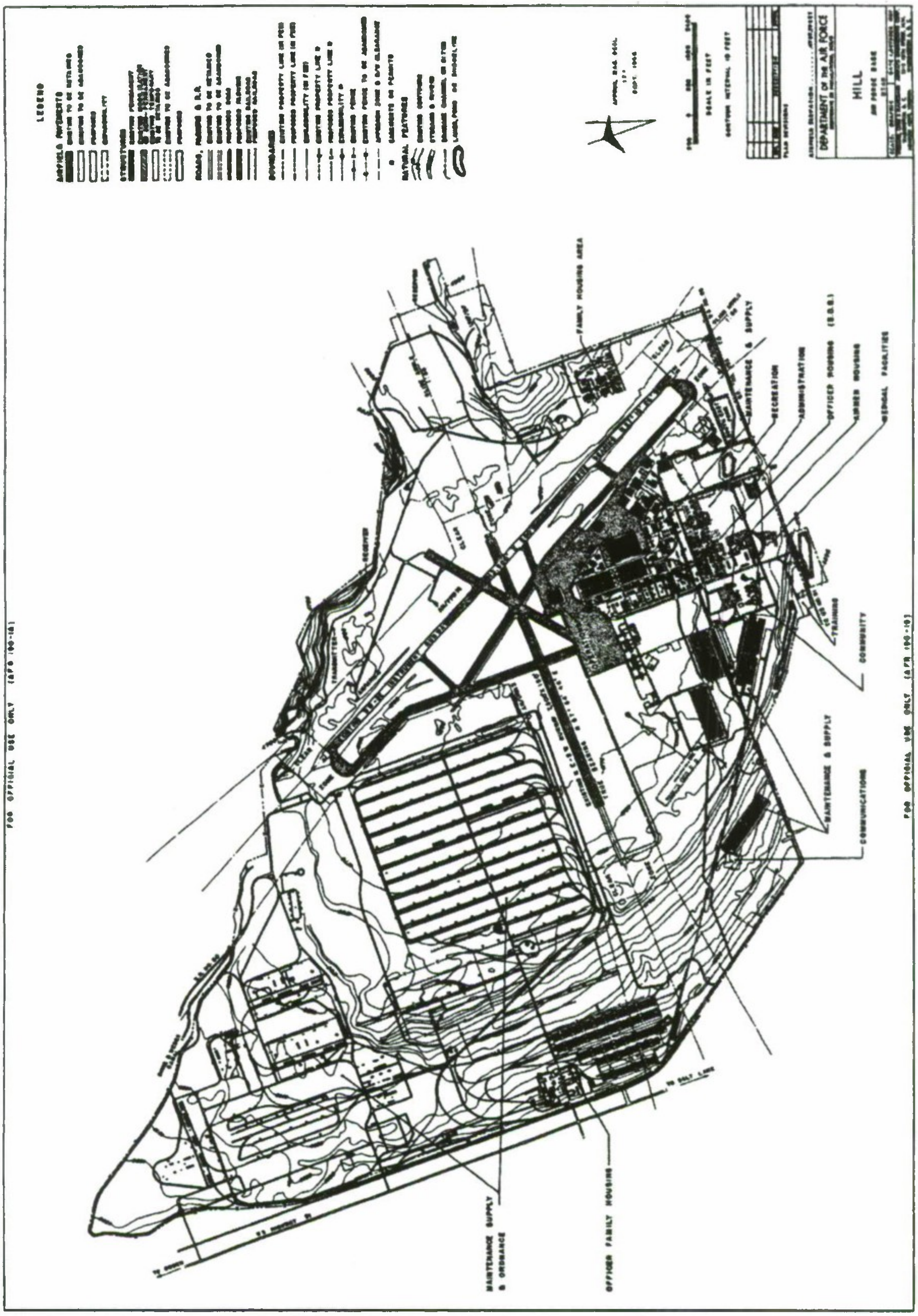

Plate 78: Directorate of Installations, Headquarters United States Air Force. Master Plan for Hill Air Force Base, October 1957. Former Army arsenal in the northwest quadrant. Collection of K.J. Weitze.

and additionally, the annual resupply of AC&W radar squadrons in Alaska through Project Mona Lisa. In a parallel manner, the Middletown AMA at Olmsted Air Force Base in Pennsylvania handled the needs of Northeast Air Command. (Selected Ogden taskings to support Alaskan Air Command began shifting to the Sacramento AMA at McClellan in late 1958.) In August 1955, Headquarters Air Materiel Command split the logistics support of Canada between Ogden (west) and Middletown (east). As a result of the command's decentralization of contractor management responsibilities to its depots, Ogden became responsible for the Air Force Plant Representative Office at Northrop Aircraft in Hawthorne (within greater Los Angeles), California, when the command shifted depot management of the Northrop F-89 from the San Bernardino AMA at Norton, to Hill in 1953. (The prime depot mission for Northrop aircraft parts and selected maintenance had arrived formally the year before, also transferred from the San Bernardino AMA.) Other changes in responsibilities followed, as missions moved among the depots, with a new assignment in one area often offsetting a loss in another. The early 1950s were fluid at Hill, which was still positioning for a sustainable Cold War role. During 1950-1952, base personnel continued to modify and overhaul the B-26 and B-29 propeller bombers of World War II.[27]

With the grounding of all F-89s in late 1952 due to the aircraft wing's failure to withstand high stress loads, the Ogden depot received its first big assignment of the Cold War: a technical order for the modification of 106 F-89 fighter jets in January 1953. Repair for the J 35 engine, used on the F-89s, followed. Hill completed the F-89 project in late July. In October 1953, Air Materiel Command assigned major reconditioning responsibilities for another jet fighter, the F-84, to the base. Jet engine repair assignments increased, including added assignments for the J35 (the engine for some F-84 aircraft), and ones for the J33, J47, and J65. During early 1955, personnel at Hill also modified an F-84G from a "standard technical to a nuclear cloud-sampling configuration" for the Air Force Special Weapons Center at Kirtland Air Force Base in New Mexico.[28] More nuclear weapons involvement came with Project Bellboy in March 1956. Through Bellboy, personnel for the Ogden AMA modified F-89Ds to a configuration similar to that planned for the F-89J.[29] Until the F-101B and F-102 became available, only the F-89J series would carry the MB-1 Genie—a nuclear-tipped air-to-air missile planned for air defense. On paper, Ogden received prime management for the F-101 at the end of 1954, although the jet fighter (still then in prototype testing) would not arrive at the installation for maintenance and modification until 1958. The depot became a specialized repair activity for the F-102 in 1957. By the close of 1959, personnel at Hill had modified, repaired, and winterized 1,259 F-89s over a seven-year period. Maintenance personnel worked on nearly 500 F-101s by the close of 1960, and nearly 800 F-102s by 1962.[30]

During the early 1950s, the Ogden AMA additionally argued its appropriateness as a location for testing missiles, explosives, and air munitions, due to the presence of its associated ranges and the region's dry climate. Testing munitions, particularly missiles, also implied a logical site for a missiles overhaul and modification mission. As of 1951, Air Materiel Command's sister command for research and development (R&D), Air Research and Development Command (ARDC), acquired the Air Force mission for biological and chemical weapons development. While the three bases assigned key responsibilities for the mission were Eglin, Holloman, and Edwards (in Florida, New Mexico, and California, respectively), ARDC necessarily worked closely with the Army Chemical Corps. The Army had two major chemical warfare proving grounds in the continental United States, at Aberdeen in Maryland and Dugway in Utah. In place as of the early 1940s, the Dugway Proving Ground was sited in proximity to Hill. In a preview of storage and testing assignments for Air Materiel Command, ARDC placed Detachment 1 of the 6570th Chemical Test Group at Hill during 1953-1954, before moving the detachment to Dugway.[31] Air Materiel Command had placed Hill personnel at regional Army ordnance depots, including depots in Tooele, Utah, and Pueblo, Colorado, as early as 1950. Without facilities of its own for air munitions storage and test, Hill received, stored, and issued Air Force air munitions on Army property. As of 1954, Air Materiel Command explicitly

assigned the task of storing, handling, transporting, escorting, inspecting, renovating, and disposing of both chemical and biological weapons to the Ogden AMA. With the acquisition of the Ogden Arsenal in April, Hill became the focal point of all Air Force munitions logistics—including tactical training by other Air Force commands and the development of space for the storage of guided missiles, rockets, and their components.[32] In early 1955, the Ogden AMA sought Headquarters Air Materiel Command's approval as the future "munitions center for the Air Force, responsible for the receipt, storage, issue and programming, etc. for all Air Force munitions including atomic warfare, air rockets, biological, chemical and nuclear weapons."[33]

Evolution toward an air munitions mission solidified in late 1955, with the mission fully decentralized to the Ogden AMA before the close of the year, but without Army / Air Force ordnance storage issues fully resolved. Hill became the only Air Force Base to control "arsenal-type" facilities. Air Materiel Command charged the installation with the task of setting and developing ammunition depot standards for the Air Force overall. Army employees transferred from the Tooele Ordnance Depot to supervise unit training of Air Force personnel in ammunition storage and handling. Air Materiel Command next assigned the Ogden AMA the mission of Explosive Ordnance Disposal (EOD) for the United States. The responsibility for EOD overseas followed in late 1956. EOD included nuclear and special weapons, and the responsibility of clearing all Air Force bombing and gunnery ranges. The initial organization of the EOD mission included four squadrons with detachments, with a headquarters at Hill. Men were to train at the Navy EOD school located on one of the auxiliary airfields at Eglin (see Volume II, Chapter 4). Once trained, EOD squadrons provided a service to the Air Force Special Weapons Center at Kirtland. The "stand-by and enroute protection for special weapons" was a major concern at the outset of the program. Within base planning at Hill, the former Ogden Arsenal became the West Area ammunition complex. The West Area supported a mission of maintenance, modification, and renovation of air munitions; aging tests; R&D under ARDC; biological and chemical warfare storage tests; and, storage of "non-atomic" explosive components of guided missiles, including components modifications. Hill planned for personnel to use Wendover Air Force Base, to the west on the Utah / Nevada border, for the "function-testing" of complete rockets. Missiles were to undergo electronic and electrical tests, as well as x-ray checkout. Ogden was to have maintenance and repair responsibilities for the MB-1 Genie carried by the F-89, F-101, F-102, and F-106, but Headquarters Air Materiel Command assigned the special weapons supply management task to the San Antonio AMA at Kelly[34] (see Volume I, Part II and Volume II, Chapter 7).

At mid-decade, Hill possessed key new infrastructure well along in construction and was in control of the former Ogden Arsenal. The base had received the major assignment of the F-89, had made plans for the MB-1 Genie, and anticipated its first missiles management responsibility. Acquisition of the arsenal, available associated desert range lands adjacent to the Army's Dugway Proving Grounds, and an expanding relationship with aircraft contractor oversight accelerated the depot's entry into missiles work. Through the assignment of prime maintenance and supply for specific manufacturers' products, individual depots took on a more defined character. At Hill in 1956, prime contractor management included aircraft, drones, and missiles for Northrop (Hawthorne); Radioplane, a subsidiary of Northrop (Monrovia); McDonnell Aircraft (St. Louis); Aerojet-General Corporation (Azusa); and, Marquardt Aircraft (Van Nuys). With the exception of McDonnell, each of these contractors had its main facilities in greater Los Angeles. Northrop manufactured not only the F-89, but also the Snark missile (SM [Strategic Missile]-62). Radioplane manufactured the Q (the Air Force designation for drones) -4 and the Crossbow missile (GAM [guided air missile]-67), while McDonnell had contracts for the F-101, the Q-1 drone, the XV (experimental vehicle) -1 convertiplane (a combination helicopter and conventional aircraft), and the Quail (GAM-72). Aerojet and Marquardt made aircraft and missile engines, including the primary and secondary engines for the Bomarc guided missile.[35] While contractor management assignment alone did not guarantee that a

depot would continue to sustain a particular mission, such an assignment during the mid-to-late 1950s had considerable influence. For example, Air Materiel Command would first designate the Quail guided missile to the Ogden AMA, and then shift it to the Oklahoma City AMA, where the missile assignment remained. At Oklahoma City, the command coupled modification and maintenance of the Quail with those tasks for the Hound Dog missile and the B-52. The bomber and the paired missiles worked together as a single weapons system, although there were two manufacturers—Boeing and McDonnell.

The Ogden AMA's missiles assignments included Snark and Crossbow during 1953-1954, followed by the Bomarc and Bull Goose missiles before 1960. Actual maintenance and modification activities, however, did not begin on base until November 1957 when a Snark missile arrived for disassembly, as "a prototype for mechanics to train on maintenance and repair."[36] In June 1957, Air Materiel Command had revised its organization for missile responsibilities to focus on complete packages and family groups. The command's restructuring of its missiles tasking defined workload allocations across the depot bases. Air Materiel Command placed:

- ICBMs and intermediate range ballistic missiles (IRBMs) at the San Bernardino AMA at Norton in Southern California, nearest the Air Force Ballistic Missile Division (AFBMD) of ARDC;
- guided air rockets (GARs) such as Falcon, at the Middletown AMA at Olmsted in Pennsylvania;
- GAMs, including Rascal (GAM-63), Quail (GAM-72), Hound Dog (GAM-77), and Skybolt (GAM-87) at the Oklahoma City AMA at Tinker;
- tactical missiles (TMs) such as the Matador (TM-61) at the Warner Robins AMA at Robins in Georgia; and,
- interceptor missiles (IMs) such as Bomarc (IM-99), and strategic missiles (SMs) such as Snark and Bull Goose, at the Ogden AMA at Hill.[37]

Snark was a transonic surface-to-surface missile capable of reaching an altitude of 60,000 feet, with a planned range of 5,500 nautical miles. Early work at Hill was minimal while the missile was in experimental development. In mid-1956, ARDC owned five Snark missiles, with 66 missiles in manufacture at Northrop. A year later, Air Materiel Command projected that depot repair responsibilities would begin in early 1959. Efforts for Crossbow were even more rudimentary. Crossbow, a subsonic air-to-surface, antiradiation missile was to be B-47-launched, capable of traveling about 240 nautical miles at an altitude of 40,000 feet. Crossbow advanced through development and test, only to be cancelled in early 1957 before SAC procurement. The Ogden AMA did support ARDC testing of 44 Crossbow missiles released from Radioplane.[38]

Headquarters Air Materiel Command transferred the assignments of some missiles from one installation to another as planned depot maintenance matured. On paper, the Quail was a Hill tasking before the 1957 reorganization. In other cases, guided missiles missions were extremely short. The Navaho (SM-64) had been in development and test since 1946, with a late 1940s launch complex built at Holloman and with earlier work at Wendover (see below).[39] In the shuffling of depot assignments for future missiles, Navaho moved on paper from the Sacramento AMA at McClellan to Ogden AMA at Hill in June 1957—only to be cancelled the next month. The R&D vehicle for the Navaho, the X-10, however, did come at Hill for modification as a target drone for Bomarc testing. When the Quail shifted from Hill to Tinker, Air Materiel Command assigned the Bull Goose to the Ogden AMA (which had previously been tasked to Middletown). Like the Quail, the Bull Goose was a decoy missile. Men fired the Quail from the B-52, while the Bull Goose, an entirely fiberglass decoy, was launched from ground facilities that resembled what *Aviation Week* termed an "old-fashioned bread box." While the Bull Goose was still in test, and even as its prototype launcher

underwent study at the site of the American Machine and Foundry Company in Chicago (with planned erection at ARDC's Missile Test Center at Patrick in Florida), the Air Force cancelled that program as well.[40] Its assignment at Hill had been minimal, lasting 18 months.[41] For Snark, a very important SAC missile of the pilotless aircraft type, the first and only operational squadron activated at Presque Isle Air Force Base in Maine in mid-July 1959. Headquarters Air Materiel Command transferred executive management responsibility for the Snark from Aeronautical Systems Center at Wright-Patterson to the Ogden AMA in July 1960. In June 1961, nonetheless, the Air Force cancelled Snark.[42]

Bomarc was the single missile that became a long-term mission for the Ogden AMA before 1960 (Plate 79). With the mid-1957 reorganization, Air Materiel Command had transferred Bomarc from Oklahoma City to Ogden. Preliminary studies toward the Bomarc (by Boeing and the university of Michigan Aeronautical Research Center) dated to 1950, and in late 1952, ARDC had initiated testing for the missile at Patrick. By 1954, ARDC instructed Boeing to design the production missile for either a conventional or nuclear warhead. Version A of the Bomarc surface-to-air interceptor missile had a range of 150 to 200 miles. Version B increased the missile's range to 450 miles. Beginning in the late 1950s, Bomarc was the key missile for American ground-based air defense. The Air Force linked the weapons system to the computerized command and control facilities of the Semi-Automatic Ground Environment (SAGE)[43] (see Volume I, Part IV). Simultaneously with Bomarc's assignment to Hill in 1957, ARDC initiated construction for the Bomarc operational test site on Santa

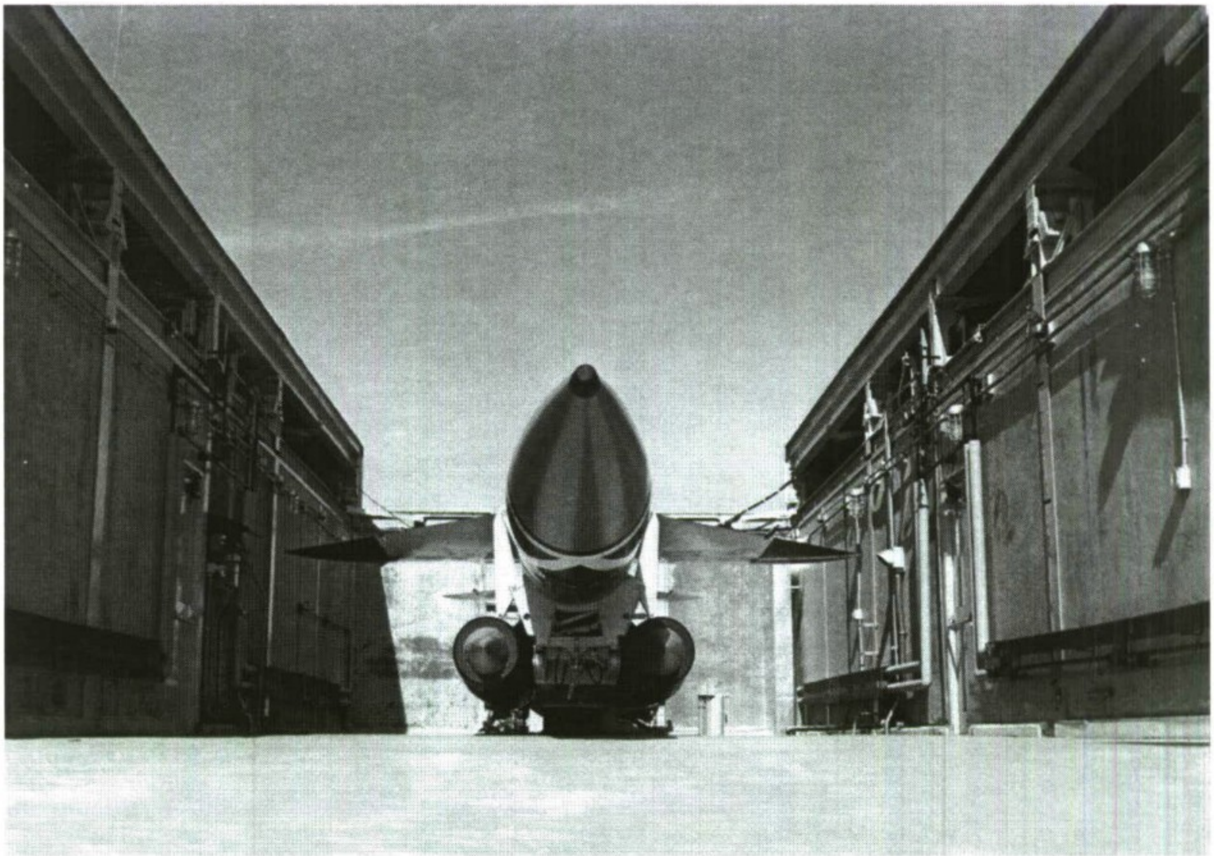

Plate 79: Boeing Aircraft. Bomarc in Test Launcher at Boeing Plant, Seattle, late 1950s. Courtesy of the History Office, Hill Air Force Base.

Rosa Island at Eglin (see Volume II, Chapter 4). ARDC had also sponsored a prototype Bomarc launcher at the Missile Test Center at Patrick during early 1957, with first launches there. Subsequent Bomarc tests employed five models of launcher built at Eglin and used the overwater expanse of the Eglin Gulf Test Range (EGTR) as well as target drones (such as the Ogden-modified X-10). Personnel first fired Bomarc at Eglin in January 1959 and had launched 140 of the test missiles by the close of 1962. As of April, ARDC completed ground tests of the ramjet engine for Bomarc at Boeing's Flight Test Center at Larson Air Force Base in eastern Washington.[44] During 1959, the first alert Bomarc squadron activated at McGuire Air Force Base in New Jersey. As finalized, Bomarc squadrons numbered 10: eight in the United States and two in Canada. Bomarc sites typically supported either 28 or 56 missiles, although at selected sites both the A and B versions went in place with as many as 84 missiles at one location. Each missile required its own launcher. Early intentions were to manufacture 6,890 Bomarc missiles (in 1953), although production stopped after 924 units of the weapon.[45]

The Ogden AMA had the responsibility for maintaining and modifying the Bomarc. The Marquardt Aircraft Company of Van Nuys (greater Los Angeles) manufactured the primary ramjet engine and selected component engine parts for Bomarc, as a subcontractor to Boeing. In early 1956, Marquardt planned to build a new plant near Hill, specifically for the manufacture of the Bomarc ramjet engine. The contractor-owned plant was one of a small cluster of missile-related manufacturing sites that would follow for the area. The Marquardt plant northwest of Hill was partially operational at Little Mountain in mid-1957. The company shipped early ramjet engines back to their Van Nuys plant for testing. Personnel at the Ogden AMA then received the ramjets from Van Nuys for storage, maintenance, and modification. From Hill, Air Materiel Command routed the Bomarc ramjet engines to the test facilities at Patrick and Eglin, and later to the 10 operational Bomarc squadron sites. To alleviate the long-distance testing in Van Nuys and bring test procedures under greater Air Force control, a government-owned, contractor-operated (GOCO) complex expanded the Marquardt plant as of late 1957. Operational two years later, the Air Force-Marquardt Jet Laboratory at Little Mountain tested the ramjet engines produced at the adjacent Marquardt plant before shipment to the Ogden AMA at Hill.[46] The first complete Bomarc missile—a test-damaged missile shipped from Patrick—arrived at Hill in February 1958,. Twenty-six buildings supported the sizable Bomarc program at Hill, including existing structures from World War II modified for specific tasks and 14 buildings in the West Area (the former Army arsenal). Special Bomarc test equipment at Hill featured temperature conditioning facilities, an ammunition drop-test tower of 1958, and a two-million volt x-ray test complex of 1957-1958 (Building 2113).[47] The x-ray facility was the largest in the region. Over time personnel at Hill used it to test for cracks, bubbles, or soft spots in rocket motors, boosters, and missile solid-propellants (as in Minuteman).[48] AFLC also modified an existing World War II building for x-ray equipment, and augmented the facility in the early 1960s to support Minuteman I.[49]

In late 1961, the Ogden AMA received its first Bomarc A missiles for major repair and overhaul (from McGuire and Suffolk Air Force Bases in New Jersey and New York, respectively). In 1962, Boeing equipped all Bomarc missiles with nuclear warheads. In January that year, the Ogden AMA acquired the first of these advanced "version B" Bomarcs.[50] At Eglin, the Bomarc test site also took on a second life as a Bomarc training facility. At Hill, Ogden AMA personnel trained men in depot-level support for the missile. Training sessions occurred not only at the base, but also at Boeing's plant in Seattle and at Air Training Command's school at Chanute Air Force Base in Illinois.[51] Beginning in 1964 with Bomarc A, and followed in 1972 with Bomarc B, depot responsibilities included modifying the Bomarc as a target drone for use at Eglin. F-101s, F-102s, F-4s, F-106s, F-15s, and F-16s fired their air-to-air weapons against Bomarc drones on the EGTR until August 1985.[52] Ratification of the Strategic Arms Limitation Talks (SALT) 1 treaty stimulated the conversion of Bomarc B to a target drone. Phaseout of the Bomarc B was a stipulation of the SALT 1

negotiations. Personnel at the Ogden Air Logistics Center (ALC) (the follow-on to the Ogden AMA in 1974) converted 79 Bomarc Bs to drones for Air Force target practice (primarily at Eglin). They converted another 125 Bomarc Bs for the Navy. Conversion of the missiles to drones continued into the early 1980s, although more Bomarc airframes existed than drone conversion kits. TAC ran the Bomarc drone target-test program and terminated it in September 1985. Disposal of the remaining 48 stored Bomarc airframes (at Tyndall Air Force Base in Florida and at the Anniston Army Depot in Alabama) became an Ogden ALC problem after two accidents with Bomarc target drones in early 1985. The missile's airframe contained a hazardous substance, thoriated magnesium. In late 1987, plans were to dump the remaining Bomarcs at sea—presumably within the ETGR.[53]

Headquarters Air Materiel Command succeeded in transitioning the Ogden AMA toward major missiles work between 1956 and 1960. The MB-1 Genie reinforced the AMA's missiles orientation. While technically not a missile, the MB-1 Genie (also known as High Card and Ding Dong) was as important to Air Defense Command's (ADC's) air defense mission as was Bomarc. ADC personnel initially fired the Genie, an unguided air-to-air rocket with a nuclear warhead, only from the F-89J. The Genie came to Ogden partially due to the depot's sustained F-89 mission (much as the Hound Dog / Quail pair went to Oklahoma City due to the preexistence of the major B-52 mission there). Air Materiel Command decided in March 1956 that Ogden should manage the F-89 Weapon System Phasing Group to dovetail with the ending of procurement for the F-89. All F-89 missions at Hill after this date would be for the existing aircraft and would incorporate modifications to carry the Genie. Efforts in 1956 encompassed Project Bellboy, with the F-89J live-firing a Genie in Operation Plumb Bob over the Nevada Test Range in July 1957.[54] (The firing over Nevada was the first and last live firing of the rocket.) Through Bellboy, Ogden personnel had reconfigured 25 F-89Ds as "Js" by January 1957. ADC split the assignment of these first F-89Js between Hamilton and Wurtsmith Air Force Bases (in California and Michigan, respectively), the Air Force Special Weapons Center at Kirtland, and the Air Force Flight Test Center at Edwards. The Flight Test Center further deployed the aircraft to Eglin and to Vincent Air Force Base in Arizona, for additional testing. The first version of the Genie had an unstable 1.5 kiloton plutonium warhead. ADC chose Hamilton and Wurtsmith as the missile's initial operational bases due to their proximity to large bodies of water (for dumping the rocket during an accident). During 1956-1957, no F-89Js flew with the Genie on board. The Los Alamos Laboratory in New Mexico, run by the University of California, had developed the Genie. Los Alamos improved later versions to allow carrying the weapon during practice air defense flights. Responsibilities for the Genie as an ammunition item were also complex. Headquarters Air Materiel Command assigned storage of the Genie nuclear warhead, as was true for the supply management task, to the Special Weapons Division at the San Antonio AMA at Kelly[55] (with physical storage at nearby Medina Base) (see Volume II, Chapter 7).

By the late 1950s, the most comprehensive missiles assignment undertaken by the Ogden AMA during the Cold War was also beginning to unfold. The AFBMD in Los Angeles selected Boeing as its contractor for the solid-propellant Minuteman ICBM in mid-October 1958. Air Materiel Command assigned the Minuteman to the Ogden AMA the following January and stationed two officers from Hill to the Ballistic Missiles Center at Norton Air Force Base in San Bernardino (see Volume II, Chapter 9). In July 1959, Air Materiel Command transferred responsibility for Boeing contract management and procurement from Oklahoma City to Ogden. The command's action placed multiple Boeing (and Boeing subcontractor) projects under management of the Ogden AMA at Hill. Simultaneously, Boeing subcontracted components of its Minuteman work to the Thiokol Chemical Corporation, the Hercules Powder Company, and Aerojet-General, with two of these companies establishing Air Force Plants (AFPs) 78 (Thiokol) and 81 (Hercules Powder) in the Salt Lake City region. Thiokol, based in Trenton, New Jersey, manufactured solid-propellant engines for missiles. Thiokol had worked on such rocket propulsion systems from 1948 forward, beginning with company projects for the Army's Redstone Arsenal in Huntsville, Alabama. Thiokol dedicated its first plant

near Brigham City in October 1957. Hercules Powder had operated a plant at Bacchus, Utah, in 1914. Hercules explosives were a component of the Honest John, Little John, Nike, Terrier, Scout, Talos, Snark, and Vanguard missiles and vehicles.

As of mid-1958, both Thiokol and Hercules had R&D contracts for the first-stage and third-stage motors of Minuteman, respectively. Aerojet-General, of Sacramento, had the contract for the second-stage motor of the ICBM. Groundbreaking for the Hercules GOCO, immediately adjacent to Hercules' early 20th century manufacturing site, occurred in early 1958. In November 1959, Thiokol received the production contract for the first-stage Minuteman motor. Agreements for its GOCO (neighboring its 1957 site) were simultaneous, with construction underway in November 1960. Boeing also established a GOCO for Minuteman manufacture. After changing company plans to establish its Minuteman assembly plant at the Hastings Naval Ordnance Depot in Nebraska, Boeing set up AFP 77 on property at Hill.[56] AFP 77 served as Boeing's assembly point for the Minuteman. Air Materiel Command transferred 49 of the 133 1400-series ammunition igloos in Hill's West Area for incorporation into the Boeing-operated plant. Boeing modified the identical concrete, earth-covered igloos, originally designed and built during 1939-1942,[57] for assembly and test work, and for storage of Minuteman motors and motors aging tests under environmentally controlled conditions (Plates 80-82).[58] Boeing also acquired existing warehouses and other miscellaneous structures within the former arsenal. The Air Force completed the plant by erecting a group of structures for Boeing's production of the Minuteman, as well as constructing missile assembly shops for the complex. The first complete Minuteman I came off the Boeing assembly lines at AFP 77 in mid-April 1962. Plant personnel produced 1,413 Minuteman I missiles by mid-decade. Final production for Minuteman III finished in November 1978.[59]

The GOCO plants of Boeing, Thiokol, and Hercules, built with proximity to Hill during 1958-1962, did not adapt any part of their contract needs to the existing facilities of Marquardt and the Air Force at Little Mountain, although the companies made some initial efforts in that direction. Marquardt anticipated completion of its ramjet engine production for Bomarc in about mid-1962, which caused that company to look for another major contract assignment for both its production plant and its GOCO laboratory test complex. Into the middle 1960s, Marquardt pushed its research for a nuclear ramjet engine and acquired contracts for components used in the Apollo spacecraft, as well as in selected missiles. The company also installed additional sophisticated test equipment at the Little Mountain site. In April 1962, the GOCO component of the facility shifted from AFLC to Air Force Systems Command (AFSC) (ARDC's successor), part of an AFP-wide shift from AFLC to AFSC for management and oversight (see Volume I, Part II). As of 1970-1971, Marquardt closed its plant at Little Mountain and moved all operations back to Southern California. At the same time, the laboratory also shut down, with real property transferred to the Air Force and with management jurisdiction shifted from AFSC back to AFLC. The laboratory remained mothballed until early 1974, when AFLC began to expand the complex as a nuclear hardness test facility for the Minuteman. During 1975, the command added a shock test facility and a linear accelerator, and during 1976-1977, a flash x-ray machine and a missile electromagnetic pulse (EMP) tester, among other facilities. As of November 1975, the former Air Force-Marquardt Jet Laboratory became the Little Mountain Test Complex, and was fully integrated into the growing Minuteman depot mission managed by the Ogden ALC.[60]

Establishing the Minuteman mission at Hill during the early 1960s was multifaceted. In addition to the associated contractor operations, the Air Force also established the Minuteman Missile Engineering Test Facility. The engineering test complex for the Minuteman, like Boeing's AFP 77, utilized land within the boundaries of the former arsenal. Designated the Hill Engineering Test Facility (HETF) during the 1960s, the complex both complemented and augmented nonassembly tasks undertaken by Boeing at AFP 77. One of the primary missions of the HETF was missile

maintenance, achieved through the erection of a recycling facility for the repair, testing, and checkout of the Minuteman. AFLC was to operate the maintenance facility, but the project was of sufficient importance to warrant oversight of the HETF's design through the joint efforts of the Directorate of Civil Engineering at Headquarters Air Force and its command-level civil engineering counterpart within Air Materiel Command / AFLC at Wright-Patterson. The HETF was under discussion as a Directorate of Civil Engineering project in June 1960.[61] After initial difficulties in achieving Congressional funding in the Military Construction Program (MCP), AFLC contracted the specialty structures needed for the HETF to Leo A. Daly of Omaha. The command scheduled design work for completion by mid-1961. Anticipated cost for the HETF's missile maintenance (recycling) facility was $2,900,000 (Building 935), including five planned disassembly / assembly buildings, one loading / unloading platform, and the modification of 12 existing storage igloos.[62] The HETF was also to receive new calibration and radiographic laboratories.[63]

AFLC augmented its program for the HETF nearly immediately. The command first increased the building program from five structures to nine (Buildings 935, 940, 945, 950, 960, 965, 970, 975, and 980) and completed this phase of construction in early 1964.[64] AFLC next added Thor IRBM shelters near the assembly buildings in 1976 (including at least Buildings 932 and 933).[65] Thor horizontal shelters, rail-retractable in their original configuration at launch complexes, were prefabricated units designed by the Southwest Research Center in San Antonio for Douglas Aircraft.[66] AFLC also set up Thor shelters on the main base at Hill and on the Hill Air Force Range at this same time. The Air Force used the shelters much like Butler buildings (see Plate 75). The Ogden AMA had acquired surplus Thor shelters directly from their manufacturer, Douglas Aircraft, at the end of 1962, following cancellation of the Thor program in Great Britain. Hill personnel erected Thor shelters at the hot pad loading and unloading area on the installation's flightline to provide protection for moving a Minuteman I in or out of a C-133B transport aircraft.[67] Leo A. Daly was best known for its design of two sequential Headquarters SAC underground command centers at Offutt Air Force Base in Omaha, Nebraska, in the middle 1950s and middle 1980s, and for the program of 65 SAC alert ready crew quarters (moleholes) built across the United States during 1958-1959. By the time of the HETF commission, Leo A. Daly had already finished its design for the missile assembly facility (Buildings 2401-2409) at Boeing's AFP 77.[68] The Air Force augmented the Minuteman Missile Engineering Test Facility (an alternate name for the HETF) by adapting a number of existing World War II buildings at Hill, paralleling efforts at the adjacent plant.[69]

AFLC also integrated other Minuteman facilities into the HETF. The command commissioned a missile launch facility and a launch control center to run tests under simulated real-world conditions.[70] The test facility, a silo (Building 11536), included an inert Minuteman and was similar to Minuteman trainers put in place at selected SAC installations hosting the operational ICBM. The Minuteman launch control center (blockhouse) at operational sites was an underground capsule-like structure where Air Force personnel managed a flight of 10 ICBMs, each emplaced in individual silos. For the Hill test facility, AFLC constructed the launch control center aboveground near the silo, utilizing space within an adjacent brick World War II building of the former arsenal. The command also placed a simulated launch equipment room inside this structure (Building 1204) (Plate 83). AFLC instrumented the launch control center to duplicate signals for alert, prelaunch, and launch, but the facility was not an operational unit. A components test building and a launch control equipment building for the Minuteman test silo compound also existed on site. The components test building featured environmentally controlled conditions that allowed personnel to check out guidance and control systems. The first name for the Minuteman I test silo, launch control center, and support structures was the Minuteman Engineering Test Facility I, later commonly referenced as HETF I. Within the Air Force, the ICBM launch site construction program was the responsibility of AFSC, and specifically of the Space and Missiles Systems Organization (SAMSO) in Southern California (which evolved through later sequential designations at Los Angeles Air Force Station / Base) (see

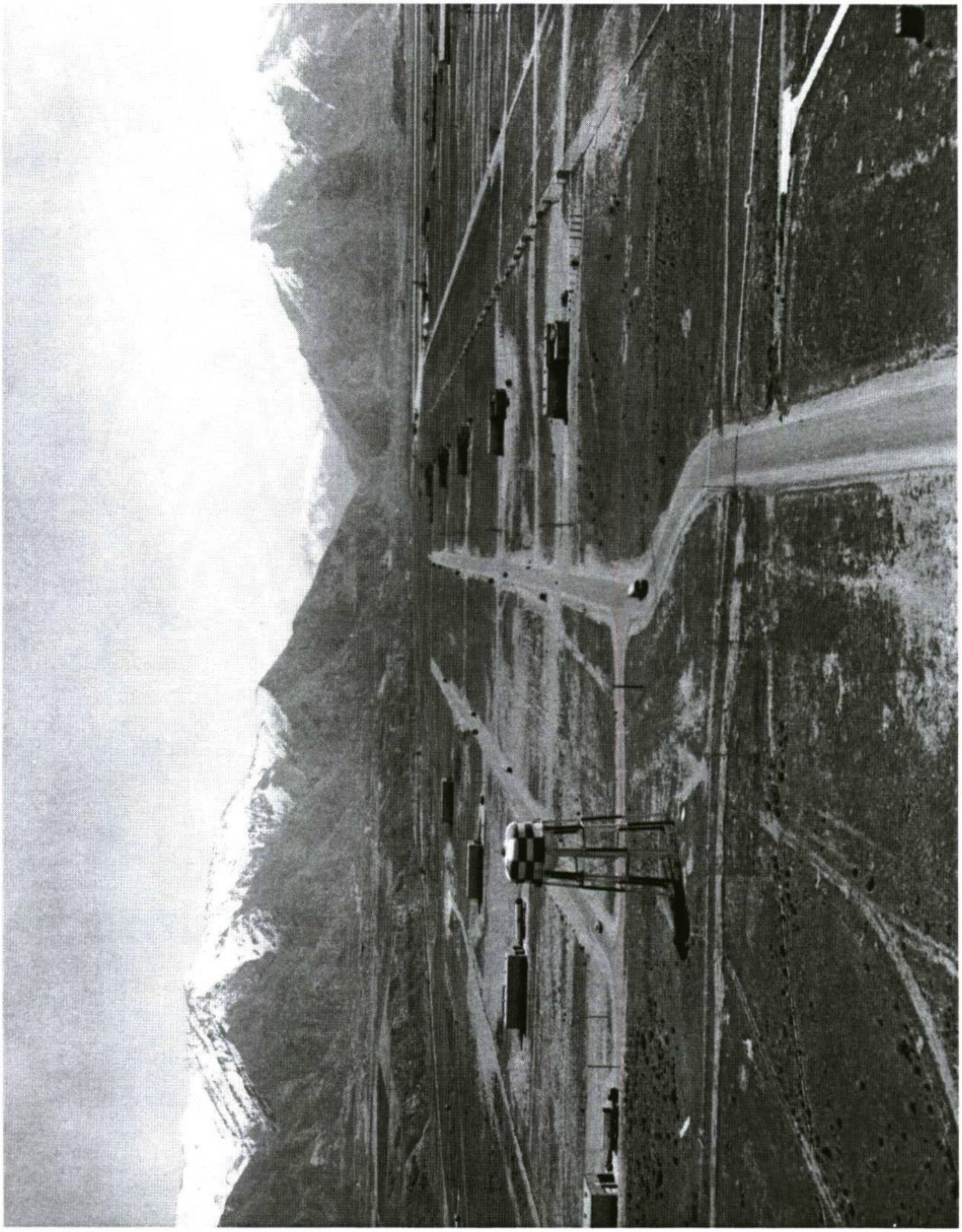

Plate 80: AFP 77, Hill Air Force Base, 22 May 1964. Courtesy of the History Office, Hill Air Force Base.

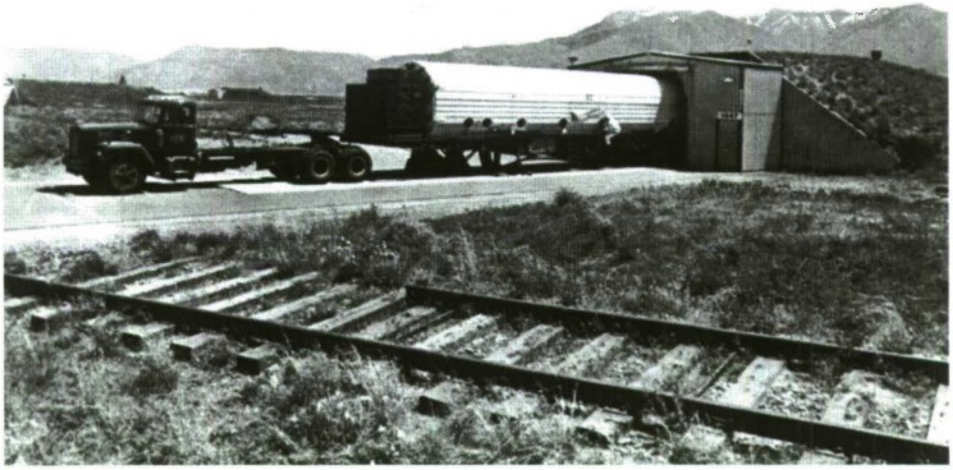

Plate 81: Building 1447, AFP 77, Hill Air Force Base, 10 June 1964. Personnel placing a Minuteman I inside the adapted storage igloo. Courtesy of the History Office, Hill Air Force Base.

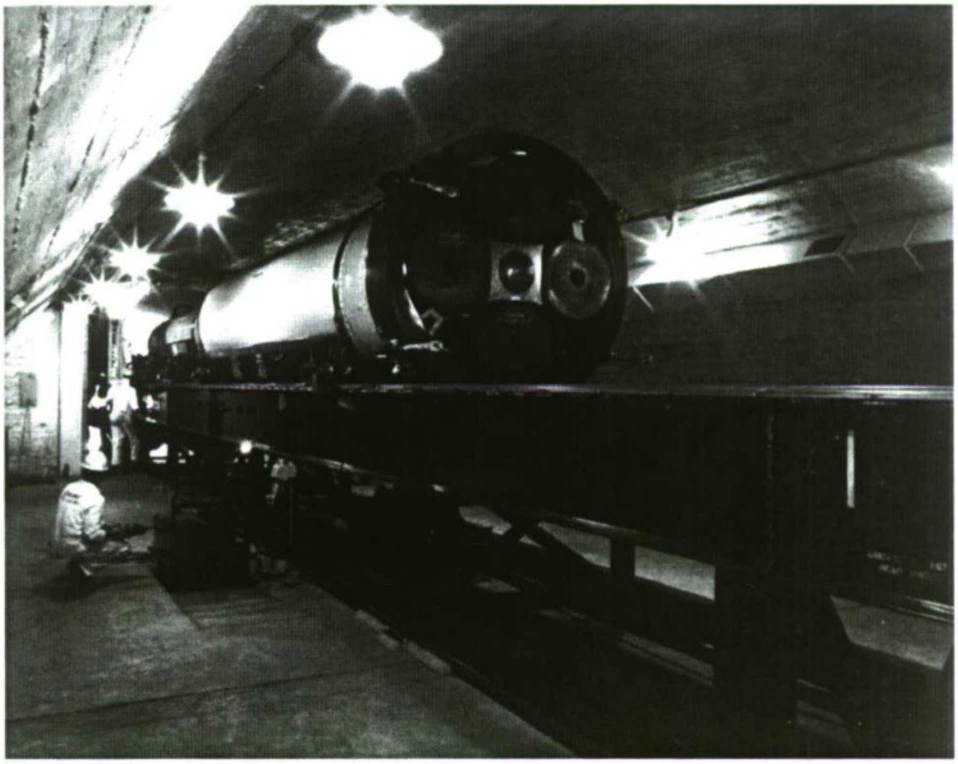

Plate 82: AFP 77, Hill Air Force Base, 1964. Minuteman I inside an adapted storage igloo. Courtesy of the History Office, Hill Air Force Base.

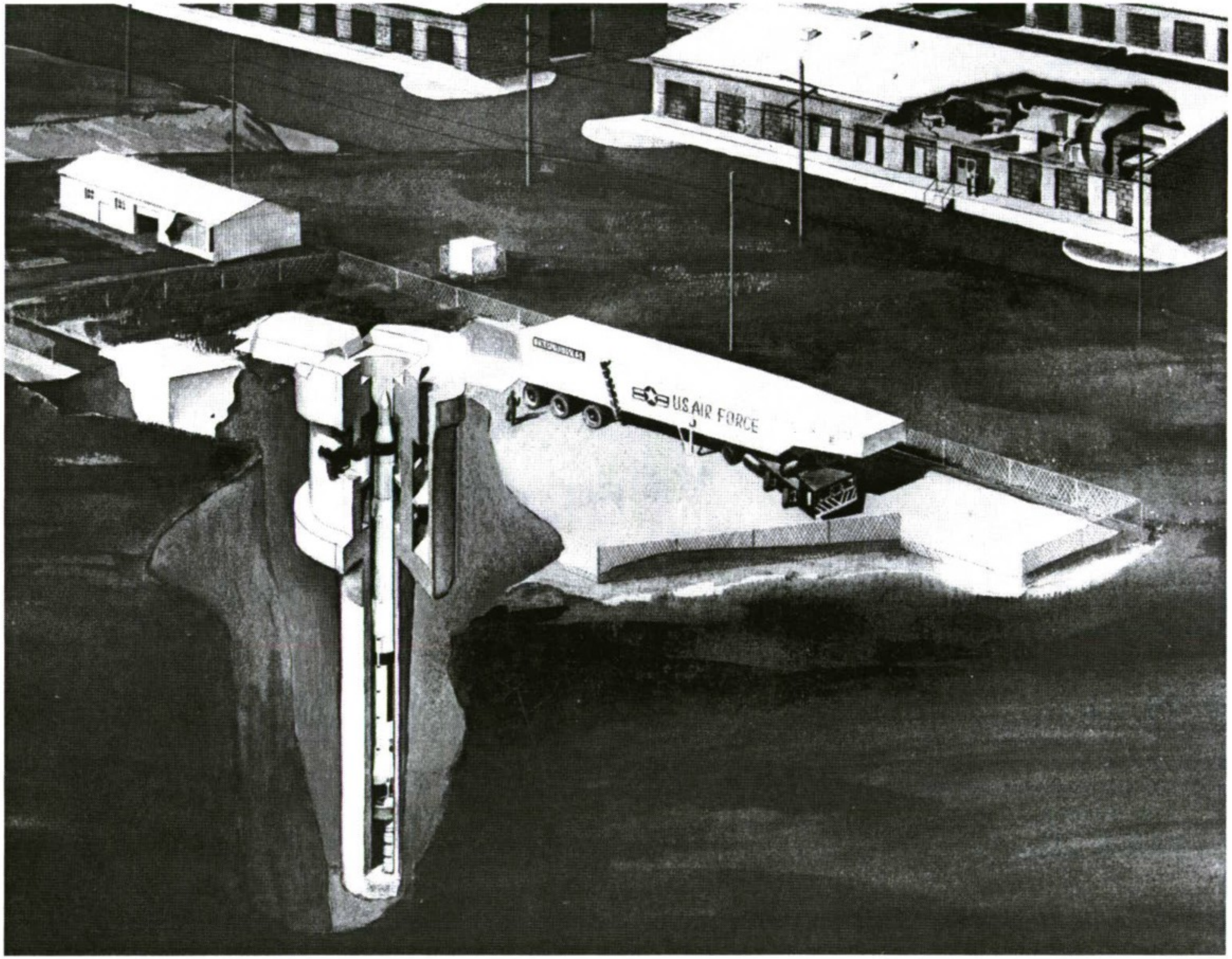

Plate 83: Hill Engineering Test Facility (HETF), Hill Air Force Base. Artist's conception of the Minuteman I test silo (Building 11536) and launch control center (inside Building 1204). Courtesy of the History Office, Hill Air Force Base.

Volume II, Chapter 9). SAMSO (first as the Western Development Division, then as AFBMD from 1957 to 1961 and as a split-house Space Systems Organization and Ballistic Systems Division from 1961 to 1967), contracted Ralph M. Parsons of Los Angeles to design and engineer the Minuteman technical facilities—including test facilities such as HETF 1 at Hill. Parsons completed drawings for the silo in August 1962 and for the launch control center in Building 1204 in December 1964.[71] Of note, Anton Tedesko of Roberts & Schaefer (the firm that designed Hill's painting and cleaning hangar in 1952-1953) served as an advisor to the Air Force and the National Aeronautics and Space Administration (NASA) for sophisticated civil engineering problem sets from 1955 to 1970. Among Tedesko's tasks was the basic planning and engineering for Minuteman ground support equipment (such as the underground launch control centers at operational Minuteman sites) and trainers (at Chanute and Vandenberg) (see Volume I, Part II).

Design and construction of the Parsons silo test complex at Hill of 1962-1965 overlapped the buildout of Minuteman operational launch sites. ARDC had conducted the first silo launches for the ICBM at Edwards, using a tethered configuration (see Volume II, Chapter 3). The eight tethered launches occurred between September 1959 and May 1960.[72] By the outset of 1960, ARDC had built a Minuteman test complex at its Missile Test Center at Patrick (on Cape Canaveral Air Force Station land). For the Patrick facilities, an aboveground gantry assisted launch.[73] The first untethered flight test of Minuteman I took place at Patrick in February 1961, with the Air Force choosing to accelerate the program by March. Simultaneously, efforts moved forward for the Titan II program. Titan II was also a silo-launched ICBM, fired from within the silo rather than after being raised to ground level via an elevator system. The first in-silo launch of an ICBM, a Titan II, was at Vandenberg in May 1961. Also in 1961, construction began on six Minuteman I silos and a launch control center at the same installation, as well as on the first operational launch facilities at Malmstrom Air Force Base in Montana. In November 1961, AFSC launched its first operational test Minuteman I from a Vandenberg silo.[74] Stimulated by the Cuban missile crisis, the Air Force put the first Minuteman flight of 10 missiles on line at Malmstrom. In July 1963, 150 Minuteman missiles and 15 launch control centers were operational surrounding the base. A year later, 12 Minuteman I squadrons stood on alert (three squadrons per wing) with 600 Minuteman I missiles.[75] By June 1965, the number of Minuteman I missiles reached 800 and, in April 1967, 200 Minuteman II ICBMs were in silos.[76]

Another component of the HETF paralleled the converted World War II 1400-series igloos of the Boeing AFP 77. AFLC initially modified 14 World War II igloos in the 1800 area for the HETF, beginning in March 1961. For these structures, the command simulated varied temperature and humidity conditions at the Minuteman operational launch sites at Malmstrom (Montana), Ellsworth (South Dakota), Minot and Grand Forks (North Dakota), F.E. Warren (Wyoming), and Whiteman (Missouri).[77] Designated the Missile Engine Surveillance Facility for Minuteman, the converted igloos created an aging laboratory (see below). AFLC contracted with the Kansas City architectural-engineering firm of Burns & McDonnell to adapt the igloos. The firm had converted four other World War II igloos into engine surveillance facilities for Minuteman during autumn 1960.[78] The second group of igloos featured two for tropic temperature and humidity conditions, and two for Arctic temperature and humidity conditions. Construction of the missile aging facilities did not occur until mid-1962. Burns & McDonnell would design several unusually-engineered hangars for the Air Force in the middle 1960s, including a cable-assisted cantilever maintenance dock for Continental Air Command (CONAC) in 1964 (within AFSC, extant at Eglin and at Hanscom Air Force Base in Massachusetts) and the alert hangar for the National Emergency Airborne Command Post (NEACP) at Offutt in early 1977.[79]

The altered igloos at Hill allowed personnel to artificially age the missile motors for Minuteman, hence supporting evaluations of long-term environmental effects on critical subsystems. The testing provided ever more accurate assessments of a Minuteman's timeline for vulnerability to failure, while

on alert in operational silos or in storage. Personnel at Hill also tested the Minuteman for response to extremely rapid temperature change, as well as under other conditions helpful for understanding reliability. Men x-rayed the Minuteman before and after all tests either at the facilities constructed as a part of the HETF during 1963-1964 (Building 985) or at a similar radiographic laboratory on Hill Air Force Range (today's UTTR) (Building 40060) that was built at the same time (Plate 84). F.C. Torkelson Company of Salt Lake City handled the design and engineering for both Minuteman x-ray facilities, as well as for horizontal and vertical rocket static test structures on Hill Air Force Range (Buildings 60015 and 60000 / 60005, built during 1963).[80] The horizontal and vertical static test stands on Hill Air Force Range allowed personnel to fire staged Minuteman motors after controlled artificial aging to check out the missiles. An early test in January 1964 evaluated a first-stage Minuteman motor that had been aged for 37 months (Plate 85). The static test stands also supported studies of Bomarc and Mace rocket motors. Minuteman longevity tests ran 15 to 37 months. In another type of test, personnel trucked Minuteman motors on long highway trips to simulate the stress conditions encountered during the return missile delivery to an operational launch squadron. The Ogden AMA then could establish appropriate maintenance and recycling schedules for the missile.[81]

Test facilities used for strictly controlled temperature and humidity aging studies for the Minuteman raise some unanswered questions. Alfred J. Nowowiejski, the Hill project engineer for the environmental test facilities, noted in the *Air Force Civil Engineer* in February 1964 that the Ogden AMA had the responsibility for operating and maintaining 14 igloos (the missile engine surveillance facility that reused 1800-area igloos) and seven silos "for...Minuteman missile aging tests." Nowowiejski commented that the Ogden AMA anticipated that the newly operational aging test

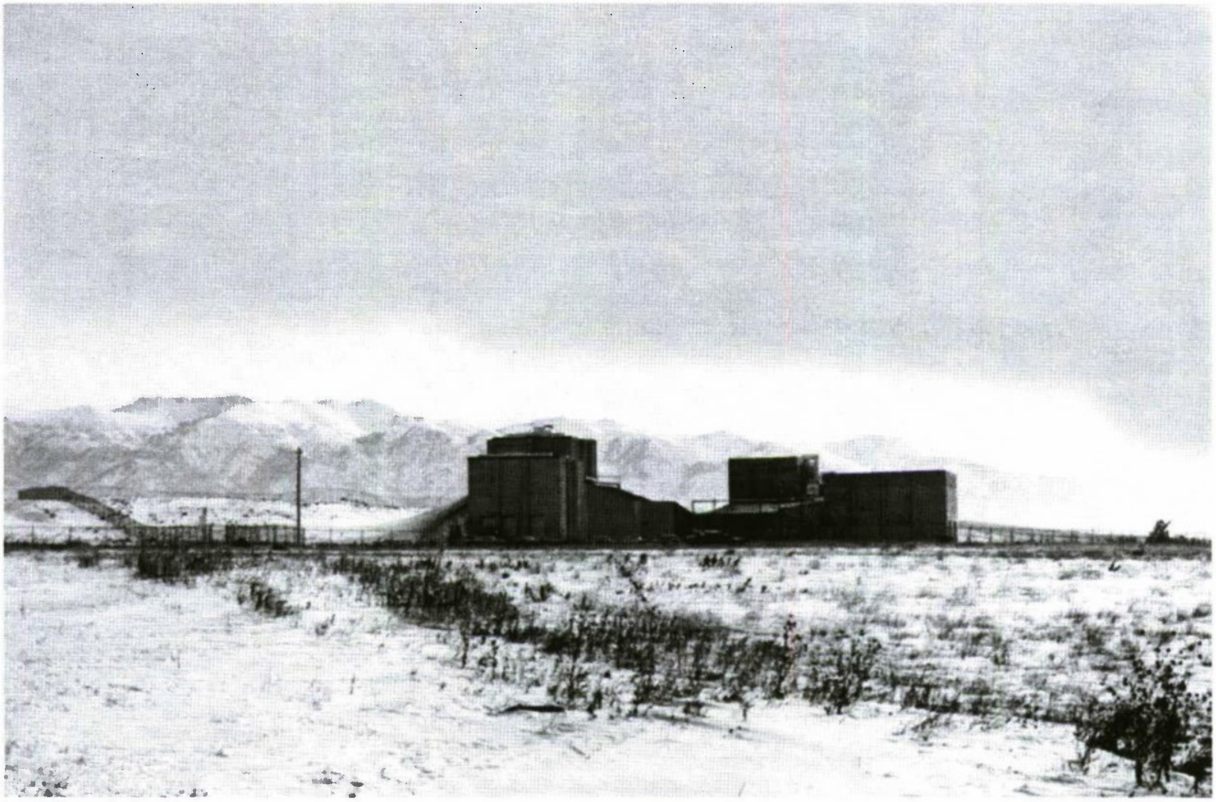

Plate 84: F.C. Torkelson Company. Radiographic Laboratory (Building 40060), Hill Air Force Range, 17 January 1964. Courtesy of the History Office, Hill Air Force Base.

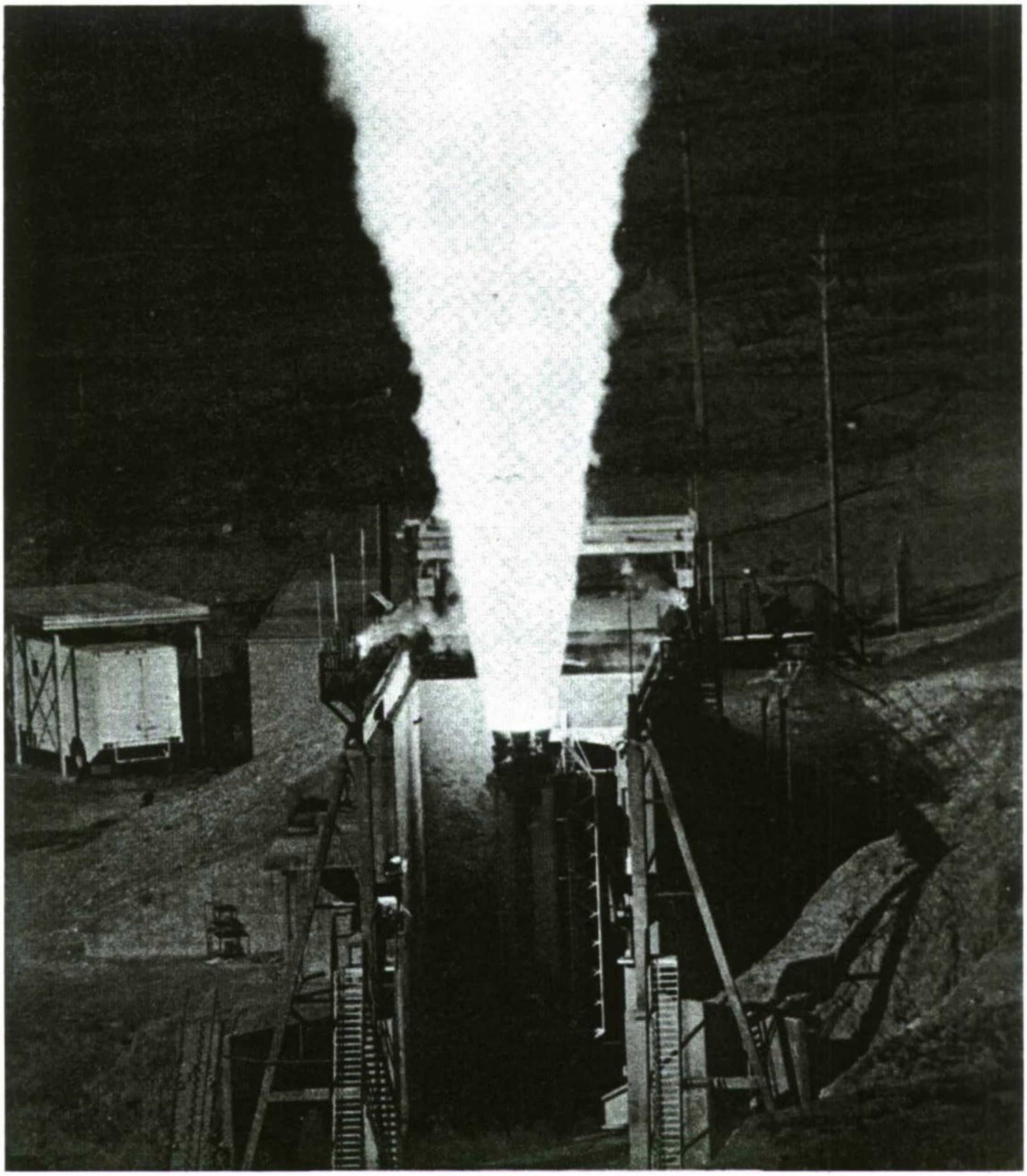

Plate 85: F.C. Torkelson Company. Vertical Static Test Stand (Buildings 60000 and 60005), Hill Air Force Range, 8 January 1964. Test-firing of a first-stage Minuteman motor after 37 months storage in aging laboratory. Courtesy of the History Office, Hill Air Force Base.

program, including the silos, would run 10 years. He further identified the assigned Hill personnel as those of the 2705th Air Munitions Wing, a wing operational between January 1960 and November 1969.[82] At Hill, only one silo was in place as of the date of the article, although a second—specific to a slightly deeper silo designed for Minuteman II, was in planning by 1964 and built in 1967. The two Hill Minuteman silos (Buildings 11536 and 11539) are confirmed aging test facilities. Configuration of the initial Hill silo is assumed to be equivalent to that for the Minuteman I silos under construction during the same period, at 78 feet deep and 12 feet in diameter. The bottom 15-feet of the silo allowed for the structure's blast pit, with the missile resting on resilient supports above it.[83] The Hill

Minuteman II silo of 1964-1967 was a little over 90 feet deep and maintained the 12-foot silo diameter of Minuteman I. The first silos of 90-foot depth went in place at Grand Forks and for an added squadron of missiles at Malmstrom. The Minuteman II silos at Grand Forks and Malmstrom were under construction during 1964-1966.[84] The seven aging silos used to support Hill's testing are anticipated as including the two at Hill for the Minuteman I and the Minuteman II, and five constructed on the bases managing operational Minuteman squadrons. AFLC may have located the five aging silos at Malmstrom, Ellsworth, Minot, Whiteman, and F.E. Warren (Minuteman wings I-V), or at some other combination of Minuteman operational, test, or training facilities nationwide.

As of 1960, the Ogden AMA also began to make extensive use of the ranges associated with the installation. Air Materiel Command redesignated the Newfoundland Mountain Air Force Range as the Hill Air Force Range in October 1960. The range included nearly 350,000 acres of land, with 860,000 acres of defined air space.[85] By late 1960, the Directorate of Civil Engineering at Headquarters Air Force planned for multiple new facilities on the Hill Air Force Range under the FY 1962 program to "provide an air munitions surveillance capability for the Air Force." The Air Force budgeted approximately $6.5 million for the project. Air Materiel Command selected F.C. Torkelson as the architect-engineer for the complex of anticipated technical facilities.[86] In early 1961, the Directorate of Civil Engineering deleted the Hill Air Force Range facilities from the FY 1962 program as a result of a conference between the Senate and the House Armed Services Committee and considered resiting them on the Army's Dugway Proving Ground to the immediate south.[87] Technical facilities for the Hill Air Force Range resurfaced in the MCP for FY 1963. Congress authorized funding for 17 items comprising a "surveillance complex for the large solid propellant motors [for Minuteman] throughout their operational life." The Directorate of Civil Engineering listed the cost, up from 1960, as $7,581,000. AFLC scheduled completion of the new range facilities for June 1964.[88]

The Hill Air Force Range of the 1960s derived from a group of ranges expanding west and southwest of the Great Salt Lake, extending to the Utah / Nevada border. Wendover Bombing and Gunnery Range, in conjunction with Wendover Army Air Field (in the later 1940s and 1950s, Wendover Air Force Base), was the first of the ranges established. Training and practice runs for dropping the atomic bombs over Hiroshima and Nagasaki had taken place at Wendover during early 1945. In addition, the Wendover Bombing and Gunnery Range had supported testing of captured German V (Vergeltung / Vengeance) -1 bombs, from which Air Materiel Command developed the JB (jet bomb) weapons series. During 1944-1945, the command also tested glide bombs on the South Range, a range to the east of the Wendover Bombing and Gunnery Range. Sited to the immediate north of the Dugway Proving Ground, the South Range became the Wendover Air Force Range. During late World War II, the Air Proving Ground at Eglin and the National Defense Research Committee (NDRC) both had detachments at Dugway, testing very heavy bombs, glide bombs, and incendiaries on the associated ranges. Eglin's projects at Dugway featured specialized chemical weapons and target infrastructure (see Volume II, Chapter 4). Between 1946 and 1948, Air Materiel Command tested the JB-2, the Gapa (ground-to-air pilotless aircraft), and a subsonic Hughes Aircraft air-to-air guided missile using facilities at Wendover Field and its two associated ranges (Wendover Bombing and Gunnery Range and South Range). Thereafter, the command shifted early guided missiles development and testing to Holloman. Between 1948 and 1959, the Air Force used their range lands near the Dugway Proving Ground in only minor ways. SAC trained bombing crews over selected areas of what would become Hill Air Force Range, and TAC initiated live bombing practice there as of 1954, with the 461st Bombardment Wing (Light) assigned to Hill. Wendover Air Force Base came and went several times during the 1948-1957 period. The installation was operational under SAC in the late 1940s, deactivated and overseen by Hill during the early 1950s, and reopened as an independent base for TAC between 1954 and 1958. TAC renamed the range lands north of I-80 as the Newfoundland Mountain Range during its tenure at Wendover Air Force Base. The

"Newfoundland Mountain Range" included the northern portion of the older South Range / Wendover Air Force Range.[89]

Evolution toward the UTTR of 1979 began when the Air Force transferred the southern half of the South Range / Wendover Air Force Range to the Dugway Proving Ground in 1959. This action followed the closing of Wendover Air Force Base as a stand-alone installation the year before. The Air Force, however, did keep control over the South Range air space. As of about 1961, the Ogden AMA began using the composite remaining range lands east of Wendover as the newly named "Hill Air Force Range." The Ogden AMA initiated limited testing of weapons components on the Hill Air Force Range, foreshadowing the type of complex planned for Minuteman. Tests for MB-1 Genie rocket motors, as well as possible tests of an undetermined nature for the Skybolt missile (GAM-87 / AGM [air-launched, ground-attach missile]-48A) took place on the range.[90] Although planned for assignment to the Oklahoma City AMA, the Skybolt mission had been assigned to Ogden in July 1959 while the weapons system was still in early development at Douglas Aircraft. The Skybolt was an air-to-surface ballistic missile nearly 40 feet long (as compared to the 53.8-foot length of the first Minuteman I/A), launched from the B-52H. The weapon was the first ballistic missile to be fired from a bomber and had a target distance of 950 nautical miles. The Air Force intended the Skybolt as a follow-on to the Hound Dog, an air-to-air cruise missile with a nuclear warhead and a target distance of 500 miles. The Skybolt, like the Hound Dog, also featured a nuclear warhead. SAC planned to deploy the Skybolt to selected alert bases beginning in 1961.[91] Program goals were 1,000 missiles and 22 missile-equipped squadrons. Douglas built full-scale dummy Skybolt missiles, proceeding with drop tests from both American and British aircraft, but never went into production for the missile.[92] The Skybolt program faced delays and rising costs, causing the Air Force to cancel it in December 1962.

To support MB-1 Genie and Skybolt tests on the Newfoundland Mountain Range (soon, Hill Air Force Range), AFLC built modest five-cubicle igloos of standard ADC (for the Genie) and SAC (for the Hound Dog) types. (The storage magazine for the Hound Dog was probably also intended for the Skybolt. The two missiles were of similar size, with the Hound Dog 42.5 feet long.) Black & Veatch, an architectural-engineering firm of Kansas City, had designed both multicubicle storage units for the Air Force in 1955 and 1958, respectively. The Air Force erected these specialized weapons storage units at multiple ADC and SAC installations over a period of years. Their planned construction for the Newfoundland Mountain Range dated to late 1960.[93] Typically, the missiles stored in these structures had live nuclear warheads. ADC segregated its cubicle magazines for the Genie in highly secured compounds, with four to five 30-cubicle units the norm. ADC constructed the Black & Veatch compounds in support of high-priority alert missions at 23 installations of the late 1950s and early 1960s. The SAC multicubicle magazines were very similar, with larger individual bays. These structures supported the Hound Dog missile launched from B-52Gs and were often incorporated into larger SAC munitions compounds. SAC deployed the Hound Dog to 29 of its 65 bases on alert during the same years as ADC's Genie.[94] Black & Veatch was the only firm hired to design storage structures for atomic and nuclear weapons at the outset of the nuclear weapons program. The firm began its unusual assignment as a highly classified effort for Sandia Laboratories and Los Alamos in 1946. Black & Veatch designed the Q Area munitions storage facilities during the late 1940s and early 1950s, as well as the atomic and nuclear bomb stockpile sites (such as Manzano Base at Kirtland and Medina Base at Kelly) (see Volume II, Chapters 7 and 8). Headquarters Air Materiel Command was also involved in construction and initial management of these facilities (see Volume I, Part II). As was the case for igloos storing Minuteman ICBMs, the multicubicle ADC and SAC magazines built on the Newfoundland Mountain (Hill Air Force) Range housed weapons without their nuclear warheads—distinctly different from their use at operational ADC and SAC alert installations. During the early 1960s, AFLC also added Black & Veatch SAC-type igloos in the 1300 and 1400 areas at Hill.[95]

The Ogden AMA dedicated the static motor test complex on the eastern portion of the northern half of Hill Air Force Range in July 1964. AFLC personnel stored Minuteman I, II, and III, as well as Peacekeeper, missile motors at the complex—known first as Lakeside, and today as the Oasis. The facilities supported aging tests in temperature-controlled structures, as well as static firings and radiographic examination (see discussion above). The Minuteman / Peacekeeper storage area on Hill Air Force Range included structures built in three temporal clusters. The first, for Minuteman I / II, dated to 1967-1969 and included eight storage units. The Air Force built the second in an expansion during the 1970s for Minuteman III (seven units) and added the third in 1977 for the MX (altered for the final Peacekeeper in 1986) (five units) (Buildings 30201-30223).[96] The first 15 phased storage buildings were identical, each designed in March 1967 with eight bays and interior rail tracks[97] (Plate 86). When the Air Force began to upgrade from Minuteman I to II in 1966, the Ogden AMA also stored excess ICBMs at the static motor test complex on Hill Air Force Range. EOD and disposal of Minuteman motors occurred on the range as well. Work on Hill Air Force Range, as well as maintenance and testing at Hill proper, did not include the nuclear warhead for the Minuteman. Excess missiles in storage on the range were also without their warheads. Before transport from operational sites to the Hill Air Force Range / UTTR, special munitions personnel removed the warheads for transfer to inspection and testing facilities located at Medina Base, associated with the San Antonio AMA / ALC at Kelly.[98]

While construction and planning for the Minuteman test facilities were underway during 1960-1964, the 4062nd Strategic Wing (SAC) became operational at Hill to conduct tests toward a visionary

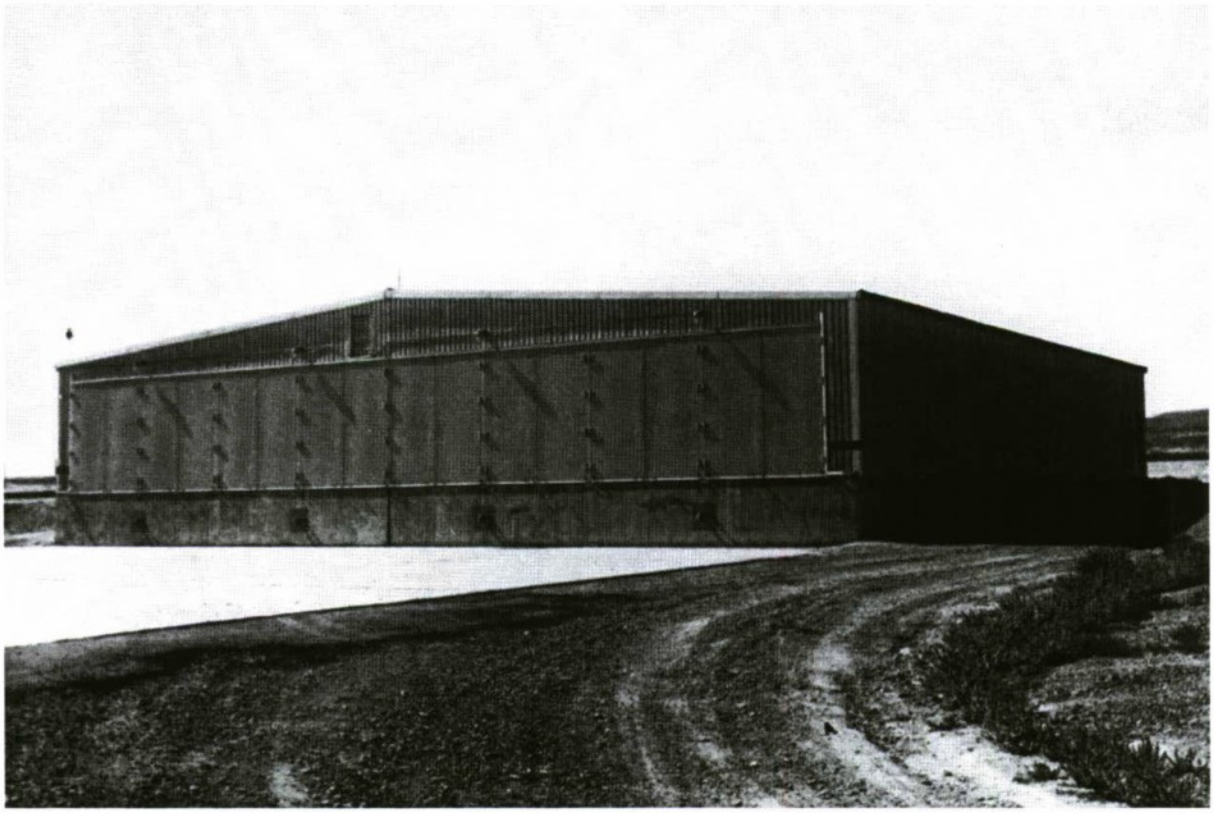

Plate 86: Minuteman Storage (one of 20 units among Buildings 30201-30223), Hill Air Force Range, late 1960s-1970s. Courtesy of the History Office, Hill Air Force Base.

deployment system for the ICBM. Stationed at the base between December 1960 and late February 1962, the 4062nd Strategic Wing ran Project Big Star, a rail deployment scheme for Minuteman I that foreshadowed Peacekeeper Rail Garrison at the end of the Cold War. In 1959, the Ballistic Missiles Committee, as well as SAC, was considering alternate ways of deploying the Minuteman. The committee favored static silos configured as a missile farm of 1,000 to 1,500 silos per location. SAC wanted to address the feasibility of mobile launchers for the Minuteman in order to remove between 50 and 150 of the ICBMs from the known target status of silo emplacement. SAC's Project Big Star planned to load Minuteman Is aboard special Air Force trains that would frequently move from place to place. The command hoped that the "rail-mobile" character of the project would prevent the Soviet Union from targeting the location of these deployed Minuteman Is. Project Big Star was one of several mobility weapons concepts under serious consideration by the American military during the late 1950s and early 1960s. The Skybolt ICBM was another, as was the Polaris sea-launched ballistic missile (SLBM) and the ship-based Hydra project.[99] SAC planned for Big Star to use 90,000 miles of commercial rail line (as was also true for Rail Garrison of the late 1980s). Sidings along the tracks were to double as primary launch sites every 25 to 100 miles, with secondary launch locations for scenarios where trains were caught between designated sidings. The SAC test program envisioned six trial runs along assigned routes in the western and central United States. SAC configured Big Star trains as one or more commercial engines that pulled command, ready-crew, power, missile, dormitory, dining, and storage cars. Individual specialized cars included up to five missile cars and three dormitory cars. SAC planned each missile car to carry one Minuteman I in a horizontal position under environmentally controlled conditions resembling those of the silos. Missile cars, similar to silos, featured shock-isolators and suspension equipment. To fire the Minuteman I, SAC personnel were to electronically open doors atop the missile cars, raise the missiles into a vertical position, and lock them in place. The missile car launch stand permitted rotation of the Minuteman I to achieve target settings. SAC initiated four preliminary test runs between May and August 1960 through Utah, Wyoming, Nebraska, Iowa, Missouri, and Colorado, using existing military rolling stock to create a train about 14 cars long. These preliminary tests did not include the specialized missile cars, nor the cars adapted as power generator units. Six existing World War II locomotive shops and shelters at Hill supported Project Big Star (Buildings 1701, 1705, 1711, 1721, 1722, and 1723).[100]

While SAC conducted the Big Star tests of 1960, the Air Force contracted with Boeing to design the Minuteman I missile train. Boeing completed a model and a full-scale mockup of a single Big Star train in mid-December 1960 (Plate 87). The Boeing trains were 11 to 15 cars long, with up to five missile cars.[101] The 4062nd Strategic Wing also activated that month to initiate planning toward production of the specialized trains and to determine the required associated infrastructure. SAC designated some of its installations in the Midwest as Mobile Unit Support Bases and intended to permanently assign Big Star crews at these locations. During 1961, with efforts barely underway, the newly elected President John F. Kennedy decided to authorize an increased deployment of Minuteman missiles in hardened silos. President Kennedy formally abandoned the rail-mobile concept by the end of the year. Early in 1962, the 4062nd Strategic Wing deactivated and the Air Force shelved Project Big Star until the idea resurfaced in 1987 as Rail Garrison. Boeing also won the $235-million contract for Rail Garrison. The goal for Big Star rail-mobile Minuteman missiles was 100; for Rail Garrison, 50 Peacekeepers. For Rail Garrison, Boeing was to produce 25 missile trains and two trains for crew instruction and equipment checkout. For the late Cold War scheme, SAC planned to garrison the missile trains in groups of three to four at each garrison installation. The Ballistic Missiles Division of AFSC was to conduct five test flights from a test train, garrisoned in mockup at Vandenberg. SAC selected the main operational installation for Rail Garrison as F.E. Warren in Wyoming, where the Air Force also refurbished 50 Minuteman silos to receive Peacekeeper missiles. The Soviet Union developed an ICBM of a parallel type in 1986. The Soviet SS-24s were immediately rail-mobile, with 36 in three rail garrisons at the close of the war in 1991.[102]

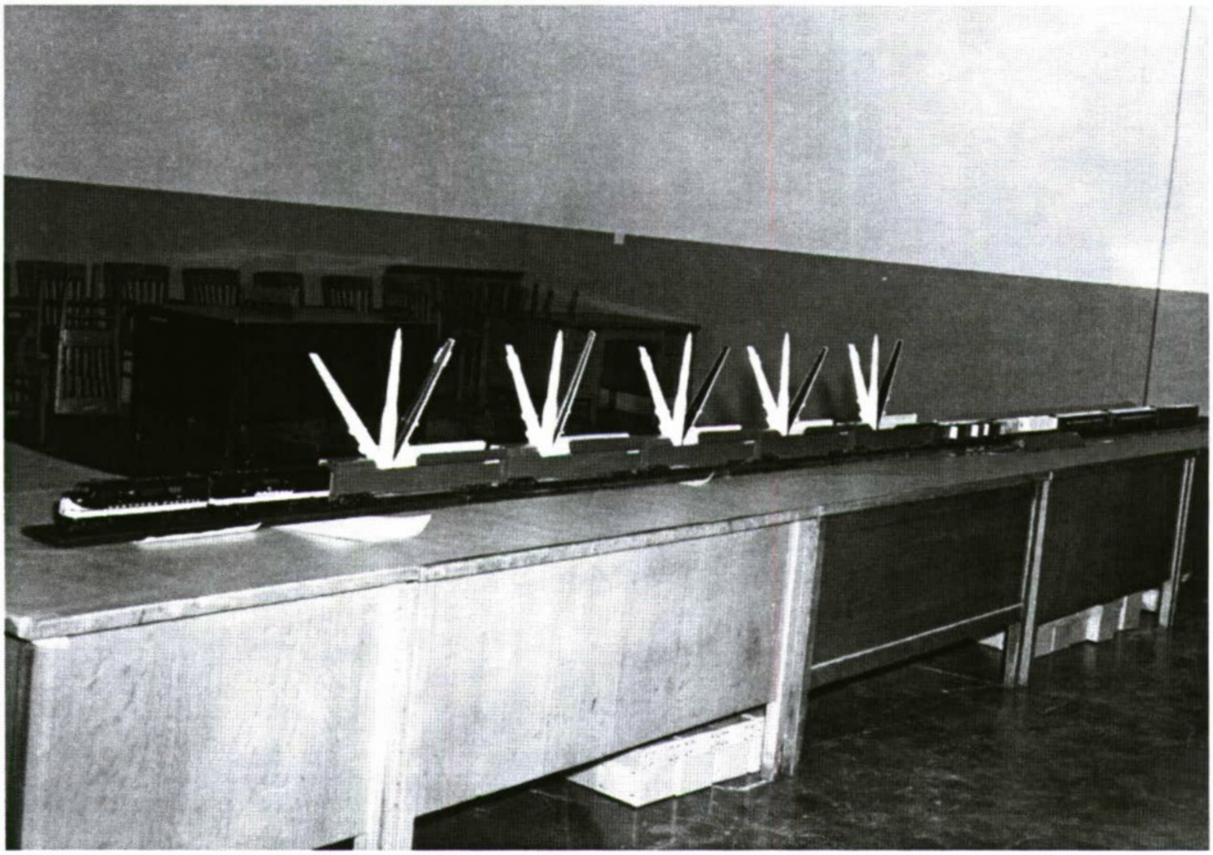

Plate 87: Boeing Aircraft. Model of Minuteman I Missile Train for Project Big Star, February 1961. Courtesy of the History Office, Hill Air Force Base.

The Ogden ALC steadily augmented its test and maintenance facilities for Minuteman I, II, and III missiles in the late 1960s and 1970s, and added responsibilities for Peacekeeper during the middle 1980s. The practice of adapting existing World War II buildings for specialty functions required by the Minuteman program at Hill continued. One example was the need for clean rooms. These facilities featured an air conditioning system that set room temperatures at 72 degrees Fahrenheit with a relative humidity of 40 percent. Filtering equipment maintained

> a maximum dust particle count tolerance of 85,000 particles per cubic foot of air for particles between 0.3 microns and 10 microns in size. The maximum for particles greater than 10 microns is 15,000.[103]

Hill engineered six clean rooms by early 1964, with three additional clean rooms in progress—one of which was among the largest in the Air Force.[104] AFLC built at least four of these facilities within World War II buildings (for example, Building 100).[105] Planned upgrading from Minuteman I to Minuteman II was underway in October 1963 before full operational deployment of the first-generation missile. The Minuteman II had a longer range, a larger warhead, and keener accuracy. With the completion of Minuteman I production at AFP 77, personnel began immediate Minuteman II assembly in August 1965. Simultaneously, Boeing initiated R&D for Minuteman III.[106] Design changes in ground test facilities at Hill accommodated the Minuteman II, with a second test silo (Building 11539), launch control center (Building 1538), and launch control equipment building (Building 11538) added on base in 1967-1969. Ralph M. Parsons designed the Minuteman II

Engineering Test Facility[107] near the Minuteman I test structures of several years earlier. The Minuteman II silo—known as HETF II—was identical to the improved Minuteman facilities built at Grand Forks and Malmstrom (also Ralph M. Parsons-designed). AFLC again constructed the Minuteman II launch control center and launch equipment capsules aboveground at Hill, placing them inside newly erected utilitarian structures (Plates 88-89). Test silo construction was a $16.5 million item, while costs for the two capsules ran about $1.6 million. The key difference between the test unit at Hill—later also modified for testing the Minuteman III—and the operational facilities at Grand Forks and Malmstrom was the placement of the launch control center aboveground rather than below, and augmentation of the facilities with an instrumentation complex and guidance test station.[108]

Late additions for Minuteman, and subsequently for the assigned MX / Peacekeeper mission, included new missile storage structures both at Hill and on Hill Air Force Range in 1975-1976 for Minuteman III, a checkout and assembly building for Minuteman III fourth-stage motors, a missile transfer building for Peacekeeper (augmenting similar facilities already in place for Minuteman), and a Peacekeeper test silo. Black & Veatch designed the checkout and assembly building for the Minuteman III fourth-stage motor, an improvement to the three-stage Minuteman II, in October 1968.[109] Alternately named the Minuteman Reentry Systems Depot (Building 2016), the structure included x-ray facilities, as well as repair and test shops. The Minuteman III featured a triple nuclear warhead, with each warhead capable of independent targeting. The multiple warhead of Minuteman III is alternately known as a multiple independently targetable reentry vehicle (MIVR) and was a major augmentation of the missile system. The fourth-stage motor for Minuteman III was a small liquid-fuel unit attached directly to the base of the missile's warhead. The added motor controlled the warheads of the missile during its final trajectory in space. The MX / Peacekeeper raised weapons technology stakes even higher by featuring a reentry vehicle with 10 independently-targetable nuclear warheads. The checkout and assembly building for the fourth-stage Minuteman III motor also accommodated maintenance and overhaul for the fourth-stage Peacekeeper motor.[110] Design and engineering of the structure by Black & Veatch illustrates the integral link between the fourth-stage motors for the Minuteman III and the Peacekeeper. Black & Veatch additionally designed a cubicle-type storage unit for hazardous explosive assemblies and components (Building 2019) as a part of their contract for the fourth-stage motor overhaul facility.[111] Most nuclear warhead and weapons storage and checkout buildings erected for the Air Force were the work of Black & Veatch throughout the Cold War. The firm also specialized in high-security surveillance systems.

AFLC augmented the Minuteman I and Minuteman II / III test silo complexes with a final aging silo for Peacekeeper during the late 1980s. The command had assigned logistics system management for the MX to the Hill ALC in September 1975, at the outset of the missile's testing. Full-scale development of the MX commenced at the end of the decade and included multiple basing studies.[112] At the close of Ronald Reagan's first year as President, he announced that SAC would deploy the MX in retrofitted Minuteman III silos. The Air Force renamed the MX as the Peacekeeper in 1983. Not until late in the decade did Congress approve Air Force-requested funding for the missile. Peacekeeper remained very controversial, due to its 10-unit warhead, its accuracy, and its basing. All decisions focused on the missile were also set against the backdrop of arms negotiations between the United States and the Soviet Union: SALT I of the early 1970s, the failed SALT II of 1979-1980, and the Strategic Arms Reduction Treaty (START) of the 1980s and early 1990s. AFSC initiated testing the Peacekeeper at Vandenberg in 1983, while Boeing received the contract to refurbish 50 Minuteman III silos at F.E. Warren for the missile. For its four final Peacekeeper test launches at Vandenberg, the command altered existing Minuteman silos at the base to simulate the operational Peacekeeper sites at F.E. Warren. Missile deployment to F.E. Warren began in December 1986, with all 50 Peacekeeper missiles in their silos as of December 1988.[113] Peacekeeper was a cold-launched missile, set into a disposable canister inside a Minuteman III silo. Unlike the Minuteman, the Peacekeeper was not placed intact into its canister, but rather was lowered into its launcher one stage

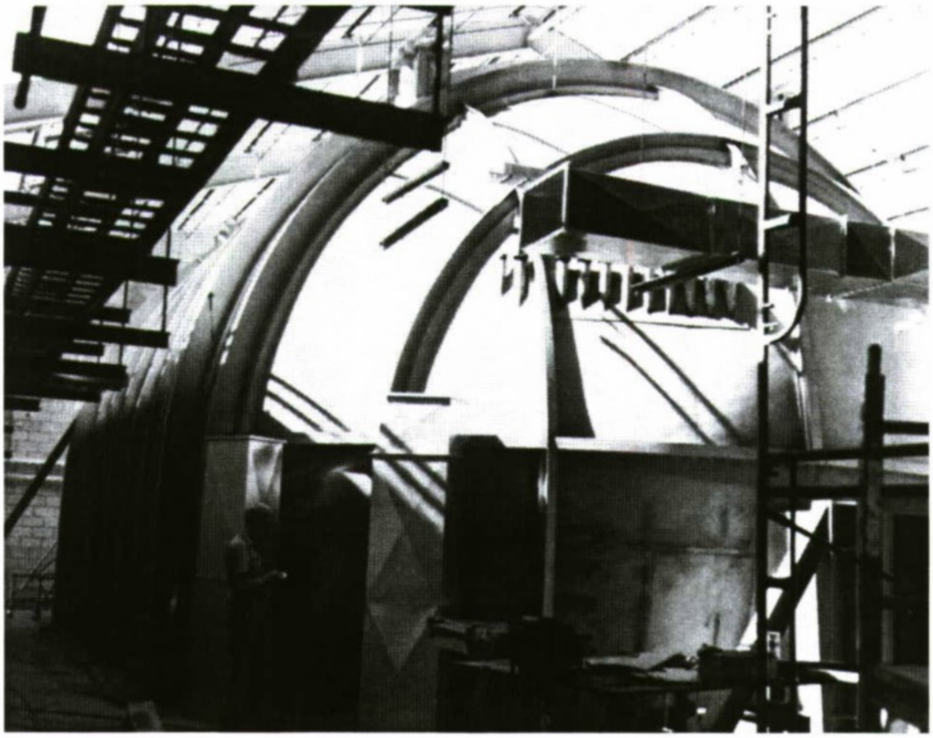

Plate 88: Ralph M. Parsons. Minuteman II Launch Control Center (Building 1538), Hill Engineering Test Facility (HETF) II, Hill Air Force Base, 31 January 1969. Courtesy of the History Office, Hill Air Force Base.

Plate 89: Inside Minuteman II Launch Control Center (Building 1538), HETF II, Hill Air Force Base, 31 January 1969. Courtesy of the History Office, Hill Air Force Base.

at a time.[114] A steam-driven mechanism lifted the Peacekeeper canister from the silo during launch. At between 150 and 300 feet altitude, the canister disintegrated and the Peacekeeper's third-stage motor fired to continue the missile on its intended trajectory.[115] In February 1987, the Omaha District of the Army Corps of Engineers completed drawings for a Peacekeeper aging silo (Building 1530) at Hill.[116] The Ogden ALC constructed the third silo for the base during 1988 as an addition to the cluster of existing Minuteman I and Minuteman II / III silo and launch control center test facilities (Plate 90). The final test silo at Hill featured a Peacekeeper canister designed to allow temperature and humidity testing of the missile, without its warhead or propellants, to guarantee the weapon system's sustained viability. At the end of the Cold War, the American ICBM force was entirely silo-based, using facilities originally constructed for Minuteman I and Minuteman II, and consisting of 450 Minuteman IIs, 550 Minuteman IIIs, and 50 Peacekeepers.[117]

While in many ways the Minuteman / Peacekeeper mission dominated activities at Hill, the installation also sustained major missions during the 1960s-1980s in support of conventional warfare. The F-101 overhaul mission continued through the 1960s, and by mid-decade Hill added selected new infrastructure for its ongoing aircraft assignments. In anticipation of the arrival of a long-term maintenance and repair mission for the F-4, for example, the Ogden AMA constructed a two-aircraft run-up facility for static engine testing. Sverdrup and Parcel of St. Louis designed the specialty hangar (Building 222) in late 1965.[118] The facility took over three years to complete and became operational in 1969. Sverdrup & Parcel handled a variety of sophisticated projects for the Air Force during the Cold War, beginning in the middle 1940s with planning for the Arnold Engineering Development Center in Tennessee (see Volume II, Chapter 1) and continuing through the design of the alternate space shuttle launch complex at Vandenberg in the late 1970s. Unlike both earlier and later run-up facilities for jet fighters, Building 222 at Hill in the middle 1960s was a reinforced concrete structure with heavy steel front door closures and vertical double rear exhaust ports. First run-up units of the late 1950s had literally relied on corrugated steel pipes placed at the rear of an aircraft's engine as oversized, portable mufflers. Whole-aircraft, steel "hush houses" combined the pseudo-muffler with varieties of prefabricated hangars after the middle 1960s. Although termed a hush house, Hill's concrete engine run-up hangar was more truly a whole-aircraft test cell, derivative in physical design from the reinforced concrete multi-cell engine test facilities of early World War II (Plate 91; see also Plate 75). The construction of Building 222 is also strongly similar to that of the hardened aircraft shelters in development through the Theater Air Base Vulnerability (TAB VEE) program for North Atlantic Treaty Organization (NATO) countries as of 1966. Different in physical configuration from the TAB VEE shelters but unlike any other known hush houses in the United States, Building 222 appeared at Hill just as Kirtland's AFWL began tests for revetments and protective aircraft shelters on Hill Air Force Range (see Volume II, Chapters 4 and 8). Both the F-101 and the F-4 were high-noise fighter aircraft during the run-up tests required to complete repair and modification. The Ogden AMA acquired the F-4 support mission worldwide by 1965, with the first aircraft arriving on base in 1966. Hill's depot role for the F-4 was especially important throughout the Vietnam War.[119]

In addition to gaining the F-4 maintenance, repair, and overhaul mission, Hill sustained other missions after the middle 1960s. The base supported the Athena missile program underway through the Ballistic Systems Division in Los Angeles (see Volume II, Chapter 9), supplied air munitions to Southeast Asia theater bases throughout the Vietnam conflict, hosted a short satellite alert mission for SAC, and acquired two F-16 missions. The Ogden AMA maintained and tested Athena rocket propulsion units, shipping them from Hill to the Athena launch complex in Green River, Utah. The Athena, like the Minuteman III, was a four-stage solid-propellant missile. The initial test launch of July 1964 from Green River toward an impact site on the White Sands Missile Range in New Mexico was only partially successful. Impact near Durango, Colorado, caused a temporary cessation of the program, although nearly 80 planned Green River launches remained.[120] From the middle 1960s through the early 1970s, Hill personnel also flew C-133s and C-141s loaded with air munitions and

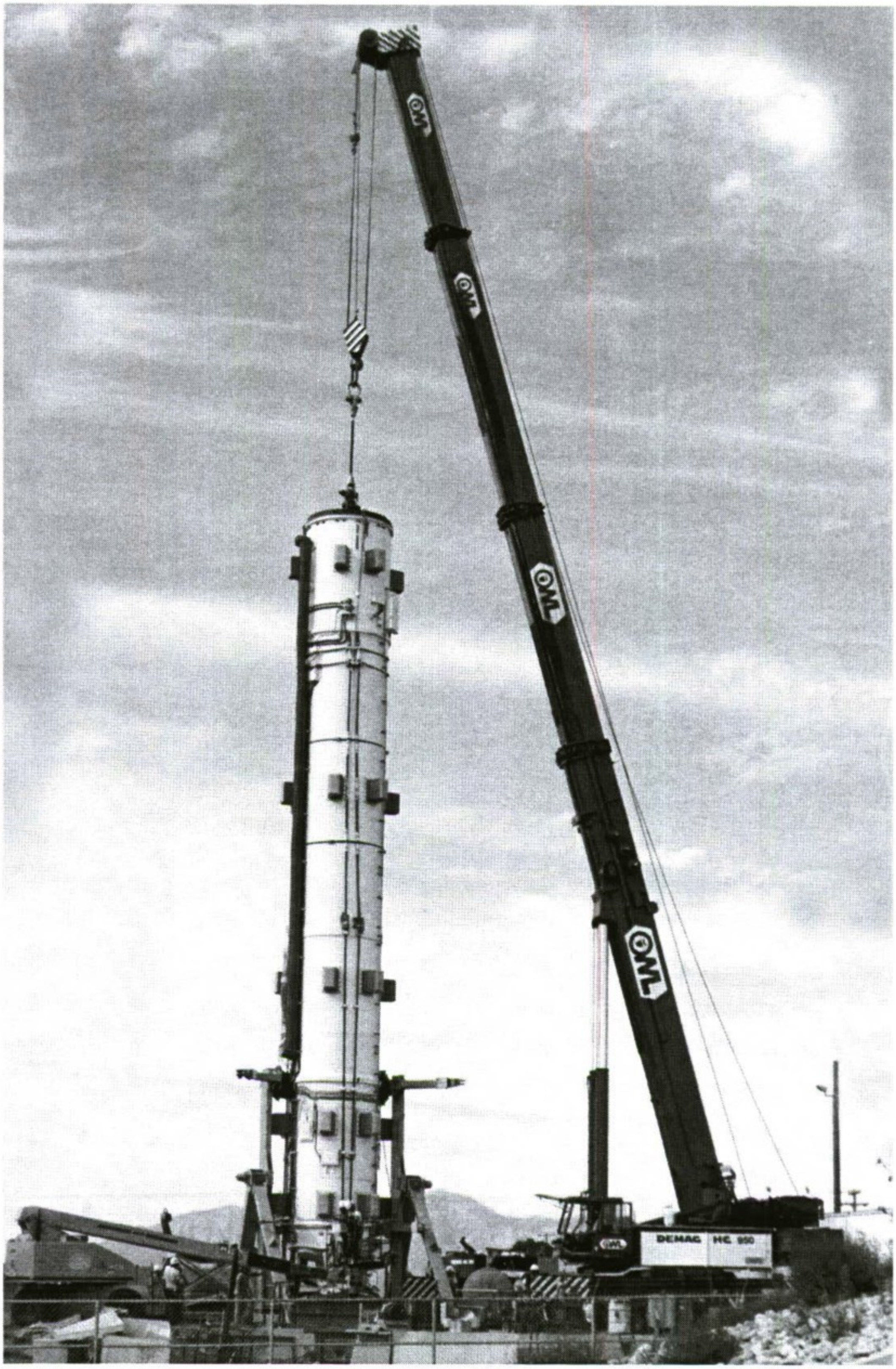

Plate 90: Peacekeeper Test Silo (Building 1530), Hill Air Force Base, ca.1988. Courtesy of the History Office, Hill Air Force Base.

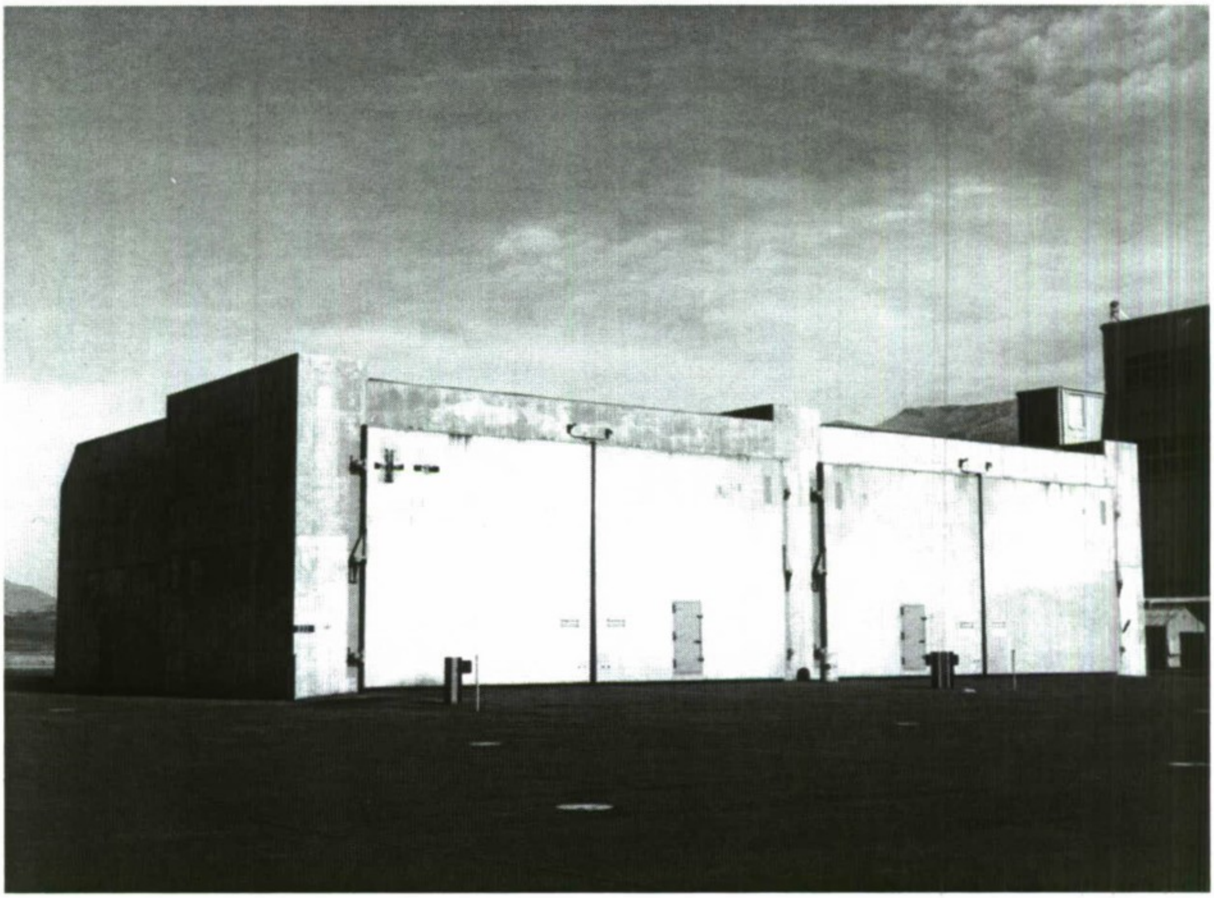

Plate 91: Sverdrup & Parcel. Run-Up Facility (Hush House) for the F-4 (Building 222), Hill Air Force Base, 14 October 1968. Courtesy of the History Office, Hill Air Force Base.

supply items to Southeast Asia. The base upgraded and expanded warehousing to support the war effort.[121] As of the late 1960s, SAC selected Hill as a satellite alert location (Buildings 772, 773, 774, 777, and 778). The latter-day SAC alert program was troubled from the start however, with the command scaling back its plans repeatedly into the early 1970s. At Hill, a detachment of B-52 bombers rotated in from Beale Air Force Base in California for 18 months during 1974-1975 (see Volume I, Part IV and Plates 110-111). For the F-16 mission, Hill received its first aircraft for maintenance in 1979. Prior to its arrival on base, the 388th Tactical Fighter Wing began a multinational maintenance training program for the F-16 as of 1978. The Ogden ALC supported F-101s, F-4s, and F-16s internationally into the 1980s, including flight testing after maintenance and overhaul.[122]

During the 1960s and 1970s, Ogden received specialized repair activity (SRA) and source of repair (SOR) responsibilities for selected weapons systems, including two sequential cruise missiles that SAC used to increase its alert capabilities during the late Cold War—the SRAM and the ALCM. Boeing held the manufacturing contract for the SRAM (AGM-69) and produced its first missile in AFP 77 in March 1972, a month after shipping its last Minuteman III for silo installation at Grand Forks. Boeing assembled its 100th SRAM by autumn the same year. AFLC assigned the Ogden AMA / ALC responsibilities for static motor testing of the SRAM and surveillance aging tests parallel to those that depot personnel ran for Minuteman. The first static firing of a SRAM motor on Hill Air Force Range took place in December 1973.[123] On receiving the completed SRAMs, SAC

deployed them to B-52s, B-1Bs, and FB-111s on alert at its installations. The SRAM replaced the Hound Dog (and the cancelled Skybolt). Typically, SAC alert squadrons that acquired the SRAM during the middle 1970s also expanded their crew quarters (moleholes) and alert aprons. SAC often placed a squadron of KC-135s[124] on alert at these same installations. Deployment of the SRAM was also part of SAC's dispersal basing plan and satellite alert. Personnel at AFP 77 assembled more than 1,500 SRAMs and provided storage, viability testing, and maintenance of the weapons system through the end of the Cold War. SAC never used the SRAM in combat, but the weapon was a powerful symbol of escalating tensions by 1980. START called out the SRAM for removal from the United States weapons arsenal, as it had Rail Garrison. SAC dropped the SRAM from its inventory in 1994 to comply with the treaty.[125]

Late Cold War missions at Hill included testing of RTVs on Hill Air Force Range during the middle 1970s, program management for the Maverick electro-optically guided air-to-surface missile (AGM-65A) as of the late 1970s, maintenance and overhaul for the ALCM during the 1980s, and support of the developmental testing phase for the Small ICBM (SICBM) program of the late 1980s (cancelled before missile production).[126] The ALCM was the follow-on to the SRAM. Boeing designed and tested the ALCM, and subsequently won the contract to produce the sophisticated cruise missile. Production of the ALCM began in 1980. Boeing assembled 1,715 missiles by the close of manufacture in 1986. Although Boeing did not manufacture the ALCM in AFP 77 at Hill, the Ogden ALC maintained the ALCM using SRAM facilities returned from Boeing to the Air Force after the plant closed in 1979. Ogden also supported the upgraded follow-on for the ALCM.[127] As was the case for the SRAM, SAC often incorporated the deployment of the ALCM into an expansion of its alert facilities at certain bases during the middle 1980s. Alert facilities augmented in the middle 1970s or in the middle 1980s typically doubled the size of their late 1950s moleholes through additions. At some SAC installations, improvements occurred at both times. For example, at Barksdale Air Force Base in Louisiana, SAC enlarged its crew quarters and extended its herringbone alert apron from five to seven aircraft parking stubs in the middle 1970s. The command lengthened the alert apron a second time in the middle 1980s, from seven to nine parking stubs. Each augmentation was tied to upgraded weapons deployment: first, the SRAM and then, the ALCM. At other bases, such as Grand Forks, receipt of the B-1B accompanied deployment of the ALCM (and expansion of the SAC alert crew quarters).[128]

Activities at Hill Air Force Range supported both conventional and nuclear warfare during these final decades. The range featured a variety of target structures for air munitions testing pertinent to the Vietnam War after 1965. Configurations of targets included concentric-circle bombing patterns and radar reflectors that were similar to targets found on the ranges used by AFSC's Armament Development and Test Center at Eglin. The range also had areas for air-to-air practice using tow targets, as well as ground impact areas for surface-to-surface missiles and fired salvo rounds. The Eagle Range complex, situated within the Hill Air Force Range, additionally offered a grouping of scorable bombing and strafing targets, while a helicopter air-to-ground training area within the range accommodated live and inert bombing practice in designated zones as of the middle 1970s. The UTTR (incorporating Hill Air Force Range as of 1979) established a Gatling gun firing area in the early 1980s. Other tests on the range after the middle 1960s included ones for weapons propagation under different storage conditions and focused on types and placement of storage structures, laser guided bomb experiments (from 1978 forward), and impaler studies for the Minuteman, among others. One particularly notable experiment was a series of tests for the Hayman igloo, a prefabricated structure named for Department of Defense official Lowell Hayman. The Hayman igloo is a concrete-and-steel structure planned for use in theater-of-war conditions (see Volume II, Chapter 11). Personnel tested the Hayman igloo on the UTTR between 1985 and 1990. They erected Hayman igloos as a test complex to determine quantity-distance information and survivability of surrounding igloos following the massive explosion of one structure within the group. The Great

Balls of Fire test of 1988 used 500,000 pounds of explosive charge in one Hayman igloo, creating a post-test crater 200 feet deep.[129]

Beginning in 1967 and repeated in the early 1980s, the range also supported tests conducted by personnel from the AFWL and the New Mexico Engineering Research Institute (NMERI) for the long-lived, hardened aircraft shelter program run by AFSC. The idea of a protective aircraft shelter survivable in conditions of nuclear warfare dated to the early 1950s. Discussions and testing fluctuated between structures oriented toward protection in conventional warfare conditions, and those that could survive nuclear blast at certain distances from ground zero. AFSC personnel erected the first test aircraft shelter on the ranges at Eglin in 1962. By the middle 1960s, the Air Force Special Weapons Center at Kirtland was involved in key explosives testing tied to the program. Kirtland's contribution, in turn, derived from work at Wright-Patterson of the late 1940s through the middle 1950s (see Volume I, Part III, and, Volume II, Chapters 4 and 8). Following the 1960s testing for a protective aircraft shelter at Eglin, attention shifted to protective revetments and shelters for air bases in Southeast Asia and for selected installations in NATO countries. The program was long and complex, first named TAB VEE. A second program, overlapping the first, developed as Concrete Sky in 1966 with specific program goals tied to the Vietnam War. Concrete Sky included 10 phases of tests between the middle 1960s and early 1970s. The Air Proving Ground Center at Eglin served as the construction agency and testing director, while the AFWL (the follow-on designation for certain elements of the Air Force Special Weapons Center) performed ordnance tests on configurations of shelter, shelter and cover materials, and component parts, such as front-closure doors and rear apertures.

Efforts toward hardened aircraft shelter studies at Hill began in early 1967, when the Directorate of Civil Engineering at Headquarters Air Force oversaw the purchase of two double corrugated arch shelters.[130] AFSC tested one for weapons effects at Hill and one in an "in-use evaluation" at Phan Rang, Vietnam.[131] During 1967 also, the AFWL had run a two-part test of protective revetments on Hill Air Force Range, setting up test sections for five proposed revetments. Revetments included in the 1967 tests at Hill were designed by Armco, Calco, Kaiser, Republic Steel Corporation, and the Navy. AFWL personnel used 30 and 50 caliber ammunition, 20 millimeter ammunition, mortars, rockets, and a 750-pound general purpose bomb in the tests. Part one of the testing ran during September and October, part two in November. Kirtland personnel erected only the Calco, Kaiser, and Republic Steel revetments for the initial tests, using an abandoned runway at Hill Air Force Base to subject the revetments to the full-force exhaust of an F-4C fighter. The sequential tests of November included all five revetments, and featured the varied munitions in tests set up on the range. During one test event, personnel subjected a revetment to an explosion simulating the detonation of a "full F-4C bomb load" to assess the revetment's ability to protect aircraft parked in adjacent revetments from bomb fragment damage.[132] During May and June of the next year, AFWL personnel returned to Hill Air Force Range to test concrete, soil cement, soil cement bags, and steel plate as potential covers for the Concrete Sky III shelter. Personnel erected several different versions of shelter on the Hill test site. The Navy's Facilities Engineering Command included two shelters of its own in the tests. In addition, Kaiser Aluminum and Chemical Sales built a double-shell, aluminum, semicircular arch shelter on site at no cost to the government (which collapsed during earth loading and did not go through ordnance testing) and the FMC Corporation installed two aluminum armored panels. The AFWL also tested a full-height steel door on the range during 1968 during a napalm bombing exercise.[133]

Concrete Sky VIII continued munitions tests on the prototype shelter at Hill. For these tests, Prime BEEF (Base Engineering Emergency Forces) Deployment 78, an 81-man team, erected three full-size, half-length concrete-covered trussless steel shelters with supporting closures, endwalls, revetments, and parapets, on Hill Air Force Range between March and May 1969. During the second

phase of the project, between May and July, an 18-man Prime BEEF Deployment 78 team maintained the shelters and revetments during Hill ordnance tests.[134] Concrete Sky VIII was "to validate the Air Force shelter system in its entirety." AFSC appointed the AFWL's Civil Engineering Branch as the test director, assigning the branch overall responsibility for the design and oversight of the effort. Both the Directorate of Civil Engineering at Headquarters Air Force and the Civil Engineering Center at Wright-Patterson participated in the Hill tests of February to July 1969[135] (Plate 92). Tests included both static and aerial delivery of a variety of weapons. The AFWL evaluated the structural responses of the shelters and shelter closures against munitions damage.[136] Laboratory personnel tested ballistic nylon, spaced steel armor, and aluminum armor shelter closures.

> A team evaluated the protective capacity of these doors against small caliber projectiles, fragments, and napalm; they also tested the shelters as a whole and the backwalls, using aerially delivered bombs and rockets as well as statically detonated bombs. Navy, Marine, and Air Force pilots delivered the aerial ordnance.

The AFWL concluded from the tests that the shelter worked well, but that the rear exhaust cell heights should be raised an additional six feet with the basic shelter design revised so that the endwall was directly attached to the shelter proper. Test personnel noted other challenges for the door closures' resistance to napalm.[137] Remnants of one of the Concrete VIII tested shelters of 1969 existed at the Papa 5 Propagation Test Site on the UTTR in late 2000 and included an approximate three-foot earthen cover not described in test reports.[138]

A second episode of hardened aircraft shelter testing took place on the UTTR during the early and middle 1980s as a part of Operation Distant Runner. While the tests of 20 years earlier had been for a first-generation protective aircraft shelter, those for Distant Runner were for a sophisticated nuclear-hardened shelter.[139] Distant Runner continued work on a second-generation shelter under Concrete Sky X, and began in 1979-1981. NMERI conducted the high explosive and nuclear simulation tests for the shelters, with Distant Runner concluding only at the end of the Cold War. Distant Runner was a part of the Defense Nuclear Agency's Theater Nuclear Forces Survivability, Security, and Safety Program. The final hardened aircraft shelter program was a complex one. The program involved multiple classified tests on the UTTR and on the New Mexico ranges of White Sands near Las Cruces, at the New Mexico Institute of Mining Technology in Socorro (smaller scale models), and on the McCormack Test Range near Kirtland. Examples of testing included ones on the UTTR using depleted uranium (DU) rounds with an F-4 parked inside the shelter; static explosion of Mk (Mark) 83 and Mk84 bombs close to the shelter;[140] 600-ton explosive tests at a predetermined range, simulating nuclear detonations; detonation of an Mk84 one meter off the floor inside the shelter; and, tower-dropped fuel-air bombs 100 to 200 feet in front of the shelter. Test personnel used DU rounds due to their extreme hardness. DU munitions can typically penetrate both heavy armor and concrete. Men also set up static tests with C (cyclotrimethylene trinitramine [plastic explosive]) -4-filled Mk83s. For these tests, personnel adapted the 36-inch diameter fiberboard forms of Sonotubes as placement devices for the explosive charges. The Sonoco Products Company of South Carolina manufactured Sonotubes as hollow concrete piers for round-column bridge supports.[141] For Distant Runner tests, personnel set the Sonotube fiberboard forms in the ground at various angles and locations before detonation, placing the C-4-filled bombs inside them. The fuel-air bombs, dropped from a test tower erected on site, created simulated overpressure conditions. For the Mk84 test, personnel placed the bomb inside the shelter after removing the F-4. The test occurred after the main shelter test activities had been dormant for about a year. It was this test that damaged the shelter. The explosion pushed the front-closure doors out 70 feet, simultaneously picking up the structure and setting it back down. The blast cut the shelter in half across the middle and caused it to partially collapse (Plate 93). The shelter was still standing at the Geneva Test Site on the UTTR in late 2000.[142]

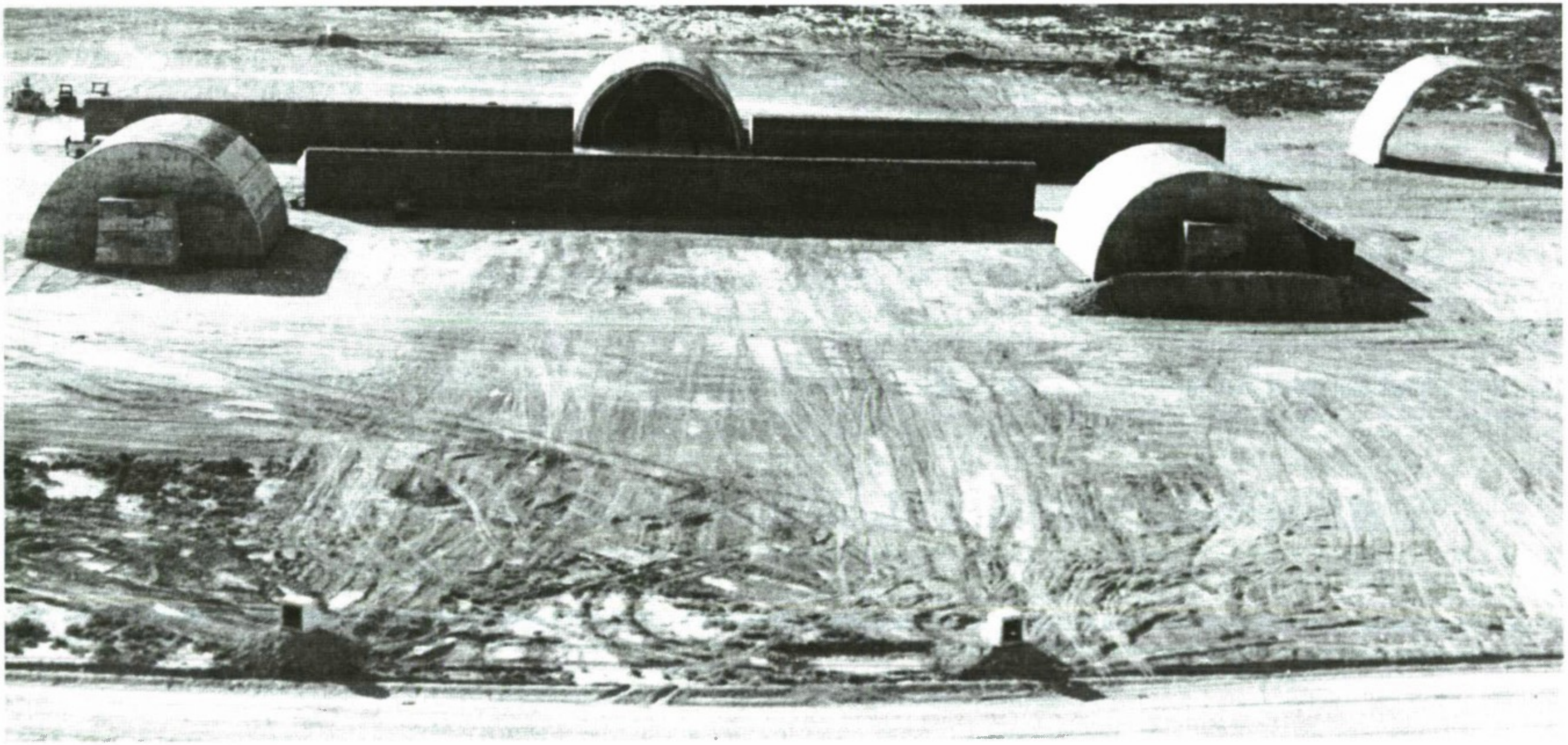

Plate 92: Concrete Sky VIII, Papa 5 Propagation Test Site, Hill Air Force Range, June 1969. Shelters prior to start of testing. In *An Annotated Bibliography of Civil Engineering Research*, Technical Report No. AFWL-TR-69-179, February 1970. The remnants of one shelter remained at the test site in late 2000.

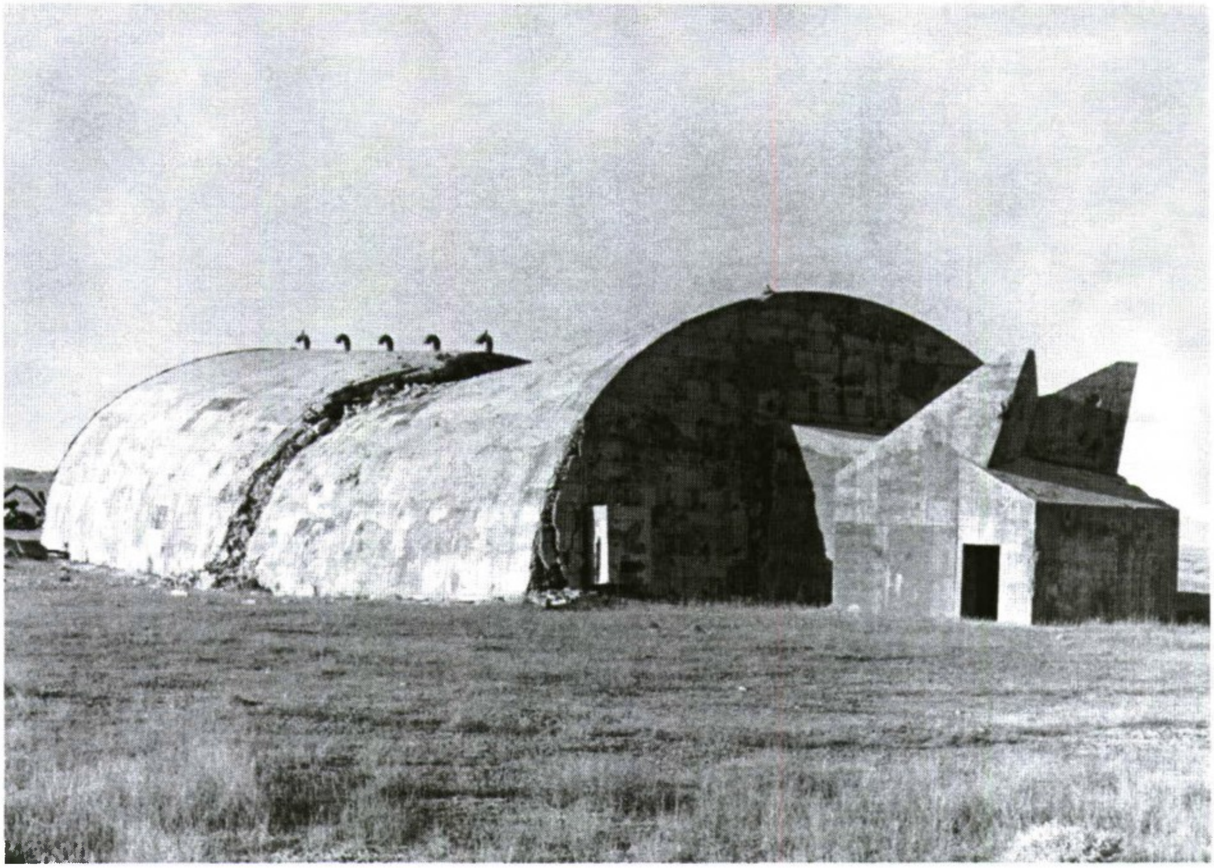

Plate 93: Operation Distant Runner Hardened Aircraft Shelter, Geneva Test Site, Utah Test and Training Range (UTTR), ca.1986. Photograph of 1 November 2000. K.J. Weitze for EDAW, Inc.

Key Associated Architects and Engineers

Several architectural-engineering firms of national significance executed designs for buildings and structures at Hill Air Force Base and the Hill Air Force Range / UTTR during the Cold War. Firms included those below, with many discussed in Volume I or in other chapters of Volume II, as noted:

- Black & Veatch, of Kansas City (Volume II, Chapter 4);
- Burns & McDonnell, of Kansas City (Volume II, Chapter 5);
- Leo A. Daly, of Omaha (Volume II, Chapter 4);
- L.P. Kooken, of Baltimore (Volume I, Part II);
- Ralph M. Parsons Company, of Los Angeles (Volume II, Chapter 3);
- Roberts & Schaefer, of Chicago; and,
- Sverdrup & Parcel, of St. Louis (Volume II, Chapter 1).

Roberts & Schaefer

Colonel Warren R. Roberts, a civil engineer, established the Warren R. Roberts Company in 1896. Roberts & Schaefer originated as a structural design service for the cement, minerals, and grain industries of the upper Midwest. Colonel Roberts formalized a partnership with a University of

Illinois classmate J.V. Schaefer in 1904. Schaefer had previously worked for LinkBelt in their coal washery department. Roberts & Schaefer specialized in industrial design, particularly for processing plants and storage facilities for coal, cement, minerals, and stone. In the middle 1920s, the firm developed a relationship with the German architectural-engineering firm of Dykerhoff & Widmann. As of 1925, John Kalinka of Dykerhoff & Widmann hired with Roberts & Schaefer in their Chicago office. Both firms worked in industrial design, although Dykerhoff & Widmann was also substantially involved in the design and engineering of major highway and railway projects, long-span bridges, and aircraft hangars. By 1932, another Dykerhoff & Widmann engineer, Anton Tedesko (1903-1994), joined the Chicago office of Roberts & Schaefer. He brought expertise in thin-shell reinforced concrete construction, termed ZD (Zeiss-Dywidag) construction, to the United States as a joint enterprise of the German and American firms. Developed during the 1920s by leading engineers in the office of Dykerhoff & Widmann, ZD construction was of international significance as new technology. Through Tedesko, in particular, Roberts & Schaefer began designing thin-shell reinforced concrete hangars for the American military as of 1939. The first hangars were for the Navy, soon followed by major work for the Army Air Corps and Army Air Forces. (Significant examples of Tedesko's hangars for the Signal Corps and Materiel Command exist at Wright Field.) Also notable was the firm's design of very large, thin-shell reinforced concrete warehouses at Army Air Corps and Army Air Forces supply depots during the early 1940s. Tedesko's work for the Air Force after World War II included the first major hangar for the B-36. The hangar was also of thin-shell reinforced concrete construction, designed in mid-1947 and erected for SAC in the late 1940s at Rapid City (Ellsworth) Air Force Base in South Dakota and Limestone (Loring) Air Force Base in Maine. During the 1950s, the firm went on to design more hangars for the Navy and Air Force, thin-shell precast concrete panel structures for overseas Air Bases, and a major warehouse in 1957 at Olmsted Air Force Base in Pennsylvania (for the Middletown AMA), as well as making achievements in aviation structures' design and engineering in the civilian sector. From 1955 to 1971, Tedesko served as a direct advisor to the Air Force and NASA for civil engineering. Beginning in the late 1950s, he worked with the AFBMD in Los Angeles on engineering specifications for missiles infrastructure—and, in this manner, directly continued his long-standing interactions with Air Materiel Command at Wright-Patterson. Tedesko was responsible for the basic design and engineering of the Minuteman ground support facilities, including the underground launch control center and training compounds erected for the missile at Vandenberg and Chanute. (His involvement is assumed to have functioned as part of Air Force directives to Ralph M. Parsons for the final design of the Minuteman facilities.) For NASA, Tedesko designed the rail-retractable, steel-truss gantry at Launch Complex 36 at Cape Canaveral for the Atlas-Centaur vehicle in the early 1960s. The AFBMD supervised this project for NASA, along with other missile launch construction required at the site. Simultaneous with work on Launch Complex 36, Tedesko represented Roberts & Schaefer in the four-firm partnership URSAM for the design of Launch Complex 39. The partnership included architect Max O. Urban, Roberts & Schaefer (as structural engineers), Seelye, Stevenson, Value & Knecht (as civil, mechanical, and electrical engineers), and Moran, Proctor, Muser & Rutledge (as foundations engineers). Roberts & Schaefer continues in Chicago today, although have returned to a business orientation reminiscent of the firm's earliest years.[143]

---

[1] Readers can check lineage details for Hill Air Force Base in Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume I of *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). Information contained in the Hill chapter includes: source of the installation's name; current and past names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base.

[2] The Army Air Forces / Air Force defined "beneficial occupancy date" as the earliest date when personnel could occupy a facility and undertake their associated duties. A beneficial occupancy date usually occurred

prior to the completion of buildings, but not until occupancy would no longer interfere with the remaining construction.

[3] Helen Rice, *History of Ogden Air Materiel Area Hill Air Force Base 1934-1960*, volume 1 (Hill Air Force Base: Air Force Logistics Command, March 1963), 15-16.

[4] Julie L. Webster, Michael A. Pedrotty, and Aaron R. Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars: A General History, Thematic Typology, and Inventory of Aircraft Hangars and Associated Buildings on Department of Defense Installations*, USACERL Technical Report 96, draft (Champaign, Illinois: United States Army Construction and Engineering Laboratories, March 1996), 105-109; Karen J. Weitze, *Eglin Air Force Base, 1931-1999: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 100-103.

[5] Doug McChristian and Thomas G. Alexander, *From Arms to Aircraft: A Brief History of Hill Air Force Base* (Denver: National Park Service, for Air Force Materiel Command, September 1996), 2-28.

[6] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 14, 29.

[7] *Ibid*, 1-44.

[8] Air Materiel Command, *History of the Ogden Air Materiel Area 1 January – 30 June 1955*, volume 1, 64.

[9] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 45-75.

[10] Information on the runways presented in Rice's *History of Ogden Air Materiel Area* sometimes contradicts itself, with accuracy of runway lengths ambiguous for the transitional period of 1950-1951. Base personnel did extend the primary runway at both ends, visible in a period photograph, but it is unclear whether they blacktopped one or both extensions. Some accounts describe a 10,000-foot runway (7,500 feet of concrete with asphalt-treated extensions) during these years, others only one 8,700 feet long (7,500 feet of concrete with only one asphalt-treated extension).

[11] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 65, 77, 82, 84, 96.

[12] *History of the Ogden Air Materiel Area 1 January – 30 June 1955*, volume 1, 130.

[13] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 86, 96-100.

[14] Air Materiel Command (Helen Rice, David J. Hefferman, and Harry L. Bonnell): *History of the Ogden Air Materiel Area 1 January – 30 June 1956*, volume 1, 93, and, *History of the Ogden Air Materiel Area 1 July – 31 December 1955*, volume 1, 31.

[15] The civil engineering vault at Hill Air Force Base contains the only known complete set of drawings for the Special AMC Warehouse, including the full range of variants. The regional architectural-engineering firm hired to carry out the L.P. Kooken design of 1951-1952 was John A. Blume of San Francisco. See L.P. Kooken, "Hill Air Force Base Special A.M.C. Warehouse, 400' by 1400'," drawing 33-02-02, 62 sheets, 20 May 1955.

[16] *History of the Ogden Air Materiel Area 1 July – 31 December 1955*, volume 1, 31, 139.

[17] Ammann & Whitney and L.P. Kooken, "Hill Air Force Base Special A.M.C. Warehouse, 400' by 1400'," drawing 33-02-02, sheet 43 of 62, revised after 20 May 1955. See also comparative drawings for girder enhancement in "Warehouse Failures Pinpointed," *Engineering News-Record* 156, 2 (12 January 1956): 21-23.

[18] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 147; Air Materiel Command (Helen Rice and Harry L. Bonnell), *History of the Ogden Air Materiel Area 1 July – 31 December 1957*, volume 1, plate.

[19] Air Materiel Command (Helen Rice, David J. Hefferman, and Harry L. Bonnell), *History of the Ogden Air Materiel Area 1 January – 30 June 1957*, volume 1, photograph and text between 134 and 135.

[20] "Status of Architect-Engineer Contracts," memorandum from Ralph R. Moulton, Lieutenant Colonel, Assistant to the Chief, Air Installations Division, Headquarters Air Materiel Command, to the Director of Installations, Headquarters United States Air Force, 26 January 1953, in File "Architect-Engineer 1953," Box 381, Entry 494, Record Group 341, National Archives II, Maryland.

[21] Karen J. Weitze, interview with David P. Billington, Princeton University, 20 May 1999. Also, "Hangars by Roberts and Schaefer Co. Chicago New York," set of black binders with information on hangars designed ca.1939-1957, including photographs and drawings. Held in the Anton Tedesko Archives, Department of Civil Engineering, Princeton University.

[22] David P. Billington, *Thin Shell Concrete Structures* (New York: McGraw-Hill, 1982). Second edition.

[23] Anton Tedesko (Roberts & Scahefer) with Louis A. Nees and Marvin T. Koerner (Office of the Installation Engineer, Headquarters Air Materiel Command), "Special facilities for painting Air Force planes provided in long-span prestressed-concrete hangar," *Civil Engineering* 29, 1 (January 1959): 38-41; and, Robinette E. McCabe, "Giant Precast Concrete Beams," *The Military Engineer* 51, 341 (May-June 1959): 187-189.

[24] *History of the Ogden Air Materiel Area 1 January – 30 June 1956*, volume 1, 93.

[25] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 159.

[26] McChristian and Alexander, *From Arms to Aircraft*, 1996, 28.
[27] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 88-125, 141-142, 144.
[28] *History of the Ogden Air Materiel Area 1 January – 30 June 1955*, volume 1, 62.
[29] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 164.
[30] *Ibid*, 88-125, 153, 163, 171-173, 179.
[31] *Ibid*, 93.
[32] *Ibid*, 182-184.
[33] *History of the Ogden Air Materiel Area 1 January – 30 June 1955*, volume 1, 13.
[34] *History of the Ogden Air Materiel Area 1 July – 31 December 1955*, volume 1, 17-41.
[35] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 147.
[36] *History of the Ogden Air Materiel Area 1 July – 31 December 1957*, volume 1, 72.
[37] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 197.
[38] *History of the Ogden Air Materiel Area 1 July – 31 December 1955*, volume 1, 60; *History of the Ogden Air Materiel Area 1 January – 30 June 1956*, volume 1, 34-35, 37-40; *History of the Ogden Air Materiel Area 1 January – 30 June 1957*, volume 1, 31.
[39] Wendover Army Air Base had been a subinstallation of Hill in 1942-1944 and hosted testing of several experimental weapons for Air Technical Service Command and Air Materiel Command during 1944-1946. The installation transferred to SAC in 1947 and became Wendover Air Force Base until Hill assumed caretaker status during 1950-1953. TAC reactivated Wendover as a base in 1954. The installation closed in 1958 when the Wendover Bombing and Gunnery Range was once more reassigned to Hill.
[40] Michael Yaffee, "Support May Become Key Missile Role," *Aviation Week* 69, 3 (21 July 1958): 61-71.
[41] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 199-200.
[42] *Ibid*, 201.
[43] Information presented on SAGE FY1959 sites in Rice's *History of Ogden Air Materiel Area*, volume 1, of 1963, is incorrect.
[44] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 206-207.
[45] Weitze, *Eglin Air Force Base, 1931-1999*, 2001, 160-168. See also Note 46. Text in Charles G. Hibbard, Susan Weathers, and David Kendziora, *History of Hill Air Force Base* (Hill Air Force Base: Ogden Air Logistics Center, 1988) suggests that Boeing manufactured 700 Bomarc A missiles and 224 Bomarc B.
[46] Douglas C. McChristian and Jerome A. Greene, *Arsenal of the Cold War: A Survey of Potentially Significant Facilities on Property Administered by Hill Air Force Base, Utah* (Denver: National Park Service, for Air Force Materiel Command, December 1999), 283-285.
[47] "Modification of Bldg 2113 for X-Ray Facilities," October 1957.
[48] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 192.
[49] McChristian and Greene, *Arsenal of the Cold War*, 1999, 264-265.
[50] Hibbard, Weathers, and Kendziora, *History of Hill Air Force Base*, 1988, 220. Text and photographs for base history up through the early 1960s is reprinted from the Rice *History of Ogden Air Materiel Area*, volume 1, of 1963, with selected paragraphs removed or edited.
[51] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 202-211.
[52] Weitze, *Eglin Air Force Base, 1931-1999*, 2001, 168.
[53] Hibbard, Weathers, and Kendziora, *History of Hill Air Force Base*, 1988, 318-319.
[54] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 164-166, 187.
[55] Air Materiel Command, *History of the Ogden Air Materiel Area 1 July – 31 December 1956*, volume 1, 10-11,48-49.
[56] McChristian and Greene, *Arsenal of the Cold War*, 1999, 128.
[57] *Ibid*, 261.
[58] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 192, 208-209, 213-217, 230.
[59] McChristian and Greene, *Arsenal of the Cold War*, 1999, 128-148; Hibbard, Weathers, and Kendziora, *History of Hill Air Force Base*, 1988.
[60] McChristian and Greene, *Arsenal of the Cold War*, 1999, 286-289.
[61] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1960*, volume 8, 45-46.
[62] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1962*, volume 5, 19-20; Leo A. Daly: "Missile Maintenance Facility," drawing AW 35-69-03, [Building 935], 12 July 1962, and, "Disassembly-Assembly Building," drawing AW 35-69-04, [Building 940], 12 July 1962.

[63] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1960*, volume 8, 47, 52.
[64] McChristian and Greene, *Arsenal of the Cold War*, 1999, 253-255.
[65] As adapted, the Thor shelters were of two lengths, just under 76 feet and just under 100 feet. At Thor launch complexes, two horizontal shelters pulled back on rails from a centered launch pad, where personnel raised the IRBM to a vertical position. See, "Relocate Thor Shelters," 27 February 1976.
[66] "Missile Gets a Movable Shelter," *Engineering News-Record* 161, 20 (13 November 1958): 28. Douglas was the contractor for the Thor IRBM. The company subcontracted the design of the Thor shelters to Southwest Research Center, an R&D engineering business that handled many important and unusual assignments for the Department of Defense during the Cold War.
[67] Hibbard, Weathers, and Kendziora, *History of Hill Air Force Base*, 1988, 198-199.
[68] Leo A. Daly and Associates, "Missile Assembly Building. Boeing Airplane Company. Air Force Plant No. 77," 15 July 1960.
[69] McChristian and Greene, *Arsenal of the Cold War*, 1999, 188.
[70] *Ibid*, 219, 270-271.
[71] Ralph M. Parsons: "WS 133A Technical Facilities Minuteman Engineering Test Facility – 1 Launch Facility," and "WS 133A Technical Facilities Minuteman Engineering Test Facility – I Launch Control Facility," drawing series 28-09-01, 22 August 1962 and 15 December 1964.
[72] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 217.
[73] Michael Yaffee, "Missile Support Becomes Prime Cost Item," *Aviation Week* 72, 14 (4 April 1960): 65-70.
[74] John C. Lonnquest and David F. Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program*, USACERL Special Report 97/01 (Champaign, Illinois: United States Army Construction and Engineering Research Laboratories, November 1996), 246, 315.
[75] Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960* (Washington, D.C.: Office of Air Force History, 1990), 228-244.
[76] Lonnquest and Winkler, *To Defend and Deter*, 1996, 246-247.
[77] *Ibid*, 78, 248.
[78] Burns & McDonnell, "WS133A Engine Surveillance Facilities," 7 October 1960.
[79] Weitze, *Eglin Air Force Base, 1931-1999*, 2001, 217-218; Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 129.
[80] F.C. Torkelson Co.: "Rocket Test Building Vertical" and "Rocket Test Building Horizontal," December 1962.
[81] McChristian and Greene, *Arsenal of the Cold War*, 1999, 221-222, 256-258, 353.
[82] Alfred J. Nowowiejski, Project Engineer, "The Base CE and Environmental Control," *Air Force Civil Engineer* 5, 1 (February 1964): 6-8; Mueller, *Active Air Force Bases*, 1989, 243. The Air Force supported various interpretations of the meaning for the lettered coding of its missiles from the mid-1940s forward. A late 1980s definition of LGM relative to Minuteman is published in Secretary of the Air Force, Office of Public Affairs, "LGM-30 Minuteman," *United States Air Force Fact Sheet*, May 1987. In the LGM acronym, "L" is shorthand for "silo-launched," while "G" becomes "surface-attack" and "M" expands to "guided missile."
[83] Lonnquest and Winkler, *To Defend and Deter*, 1996, 254-255; Irving Stone, "Minuteman Site Poses Critical Challenge," *Aviation Week* 70, 3 (19 January 1959): 68-88; "Minuteman Launch Silo Details, Test Firing Shown," *Aviation Week* 76, 1 (1 January 1962): 21.
[84] Karen J. Weitze, *Grand Forks Air Force Base Inventory of Cold War Properties* (Plano, Texas: Geo-Marine, Inc., for Air Mobility Command, September 1996), 71-72.
[85] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 231.
[86] *History of the Directorate of Civil Engineering 1 July – 31 December 1960*, volume 8, 28, 47-48.
[87] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1961*, volume 5, 47.
[88] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1962*, volume 3, 5-6.
[89] McChristian and Greene, *Arsenal of the Cold War*, 1999, 303-342.
[90] *Ibid*, 343.
[91] Rice, *History of Ogden Air Materiel Area*, volume 1, 1963, 220-224.

---

[92] The Brookings Institute, "The U.S. Nuclear Weapons Cost Study Project: Skybolt Air-Launched Ballistic Missile (AGM-48A)," posted at www.brook.edu/FP/projects/nucwcost/skybolt.
[93] [Black & Veatch]: "Newfoundland Mountain Air Force Range Multicubicle Test Magazine ADC Type," drawing AW 33-13-01, 2 May 1960, and, "Newfoundland Mountain Air Force Range Multicubicle Test Magazine SAC Type," drawing AW 33-13-01, 2 May 1960. The drawings do not include real property numbering, although the title blocks confirm that Hill completed construction of the structures.
[94] Karen J. Weitze, *Cold War Infrastructure for Air Defense: The Fighter and Command Missions* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 76-77; Black & Veatch, "Ammo Storage, Multicubicle Magazine Base," drawing AW 33-13-19, July 1958.
[95] Black & Veatch, "Igloo, Storage Steel Arch – Mounded (SAC Type)," drawing AW 33-15-64, 10 May 1963.
[96] The earliest storage buildings are those with building numbers between 30201 and 30208; the second phase, between 30211 and 30217; the third, between 30218 and 30223. See: "Hill Air Force Range—Bldg Nrs 30201, 30202, 30203, 30204, 30205, 30206, 30207, & 30208 Cargo Door Repair," 31 December 1969, and, "Ballistic Missile Process Support Facility," 21 July 1976.
[97] McChristian and Greene, *Arsenal of the Cold War*, 1999, 410-412; "Storage, Depot, Rocket Assembly," drawing 33-39-08, 3 March 1967.
[98] McChristian and Greene, *Arsenal of the Cold War*, 1999, 192.
[99] David E. Shonerd, "Mobility Concept," in Kenneth Brown and Peter Weiser (eds.), *Ground Support Systems for Missiles and Space Vehicles* (New York: McGraw-Hill Book Company, Inc., 1961), 411-432.
[100] McChristian and Greene, *Arsenal of the Cold War*, 1999, 148-157.
[101] William S. Reed, "Minuteman Train Mockup Gains Approval," *Aviation Week* 73, 25 (19 December 1960): 30-31.
[102] Karen J. Weitze, *National Register of Historic Places Evaluation Peacekeeper Rail Garrison Complex Vandenberg Air Force Base* (Austin, Texas: Dames & Moore, Inc., for Air Force Materiel Command, April 1994), 9-12, 67.
[103] Nowowiejski, "Environmental Control," *Air Force Civil Engineer*, February 1964, 8.
[104] *Ibid.*
[105] McChristian and Greene, *Arsenal of the Cold War*, 1999, 197-198.
[106] *Ibid*, 202-212.
[107] Ralph M. Parsons, "Minuteman II Engineering Test Facility," drawing 28-09-02, 12 April 1967.
[108] McChristian and Greene, *Arsenal of the Cold War*, 1999, 222-227, 273-275.
[109] Black & Veatch, "Minuteman Reentry Systems Depot," drawing 35-32-32, 11 October 1968.
[110] McChristian and Greene, *Arsenal of the Cold War*, 1999, 263-264, 278-279.
[111] Black & Veatch, "Storage Units for Haz Exp Assemblies & Components Propulsion System Rocket Facility," drawing 35-32-32, 11 October 1968.
[112] Weitze, *Peacekeeper Rail Garrison Complex Vandenberg Air Force Base*, 1994, 8-9.
[113] Secretary of the Air Force, Office of Public Affairs, *Peacekeeper Fact Sheet*, July 1990.
[114] Hibbard, Weathers, and Kendziora, *History of Hill Air Force Base*, 1988, 312-317.
[115] McChristian and Greene, *Arsenal of the Cold War*, 1999, 234.
[116] United States Army Corps of Engineers, Omaha District, "Peacekeeper System Engineering Test Facility," February 1987.
[117] Lonnquest and Winkler, *To Defend and Deter*, 1996, 250.
[118] Sverdrup & Parcel, "Hangars, Maintenance, Engine Runup (Hush House)," 10 November 1965.
[119] Hibbard, Weathers, and Kendziora, *History of Hill Air Force Base*, 1988, 230.
[120] *Ibid*, 199-200, 221-222.
[121] *Ibid, passim.*
[122] *Ibid*, 270, 289.
[123] *Ibid*, 265-267.
[124] "KC" is the designation of a cargo ("C") aircraft converted for use as a refueling tanker.
[125] McChristian and Greene, *Arsenal of the Cold War*, 1999, 240-243.
[126] Hibbard, Weathers, and Kendziora, *History of Hill Air Force Base*, 1988, 259, 262, 318.
[127] McChristian and Greene, *Arsenal of the Cold War*, 1999, 245.
[128] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 123, 157.
[129] McChristian and Greene, *Arsenal of the Cold War*, 1999, 354-402.

---

[130] The major discussions of aircraft shelter and revetment testing at the Hill Air Force Range appear in the histories of the Air Force Weapons Laboratory for 1967, 1968, and 1969.
[131] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1967*, volume 3, 21.
[132] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1967*, volume 3, 20.
[133] Air Force Systems Command, *History of the Air Force Weapons Laboratory 1 January – 31 December 1969*, volume 1, February 1978, 43.
[134] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1969*, volume 3, 132.
[135] Mary J.C. Garcia, *An Annotated Bibliography of Civil Engineering Research*, Technical Report No. AFWL-TR-69-179, February 1970, 219-220.
[136] Weitze, *Eglin Air Force Base, 1931-1999*, 2001, 230-254, 304-310. Discussions detail the complete hardened aircraft shelter program of AFSC from the early 1960s through the end of the Cold War.
[137] *History of the Air Force Weapons Laboratory 1 January – 31 December 1969*, volume 1, 41-43.
[138] McChristian and Greene, *Arsenal of the Cold War*, 1999, 390-392.
[139] Weitze, *Eglin Air Force Base, 1931-1999*, 2001, 304-310.
[140] Mk is a standard abbreviation for "Mark," a weapons and equipment designation typically accompanied by a numeric model number.
[141] "Sonotube Fibre Forms help keep cost down," advertisement in *Civil Engineering* 27, 6 (June 1957): 146.
[142] Karen J. Weitze, informal oral interviews with former NMERI munitions test specialist Ken Bell, Kirtland Air Force Base, 8 March 2000; with Thomas Bretz, Distant Runner Project Manager, Kirtland Air Force Base, 10 March 2000; and, with Terry Smith, range manager, UTTR, 31 October 2000.
[143] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 24-35.

Chapter 7: Kelly Air Force Base

Historic Missions of the Cold War

Kelly Air Force Base served as a maintenance, modification, and repair depot for the Air Force, subsumed under Air Materiel Command and its follow-on Air Force Logistics Command (AFLC) throughout the Cold War. In 2001, the base formally completed realignment, with portions of the installation transferred to neighboring Lackland Air Force Base and the remainder to the City of San Antonio. Kelly is one of the oldest installations within the Air Force, with origins as Camp Kelly in 1917. During World War I, the base functioned as a flying school and air mechanics training center for the Army, and was also involved in the earliest American aeromedical efforts. Personnel at the depot modified a series of aircraft as air ambulances from 1918 through the 1930s. This type of specialized work continued well into the Cold War period. Kelly evolved into an Aviation General Supply Depot and an Aviation Repair Depot. The installation expanded in the late 1930s and early 1940s to support an Army Advanced Flying School. Depot missions during World War II centered on aircraft storage, engine and aircraft parts maintenance, vehicle overhaul, radio and radar maintenance, and overseas shipment. Cold War missions at Kelly Field, soon to be Kelly Air Force Base, suffered no hiatus at the end of World War II: the early war years focused on support for atomic weapons testing in the Marshall Islands at the Pacific Proving Ground. Throughout the Cold War, Kelly's continued nuclear weapons responsibilities remained strong, concentrated through the Directorate of Special Weapons established at the base. Headquarters Air Materiel Command / AFLC also assigned Kelly the task of developing and executing decontamination procedures for chemical, biological, and nuclear weapons. During the Vietnam War, the installation stored chemical defoliants and was additionally responsible for missile fuels from the early 1960s forward. Air Materiel Command designated Kelly's geographic jurisdiction as the San Antonio Air Materiel Area (SAAMA). The depot's missions included ones for the B-26 and B-29 during the Korean War, and long-term commitments for the B (bomber) -36, B-47, B-52, B-58, B-70, C (cargo) -45, C-131, C-5, F (fighter) -102, F-106, L (liaison) -5, L-23, T (trainer) -29, and T-34. Kelly continued its early maintenance training mission, as well as its established role in aircraft engine repair and logistics supply. Two unique missions were the operational test program for the XC (experimental cargo) -99, a large-sized transport aircraft based on the B-36, and logistics management for the Department of Defense working dog program, an effort handled by Air Training Command. For long periods, Kelly also participated in the lend-lease transfer of aircraft to foreign governments. Foreign officers trained in San Antonio in aircraft supply and maintenance.

The key Air Force tenant at the installation was the United States Air Force Security Service (USAFSS), an independent entity within the Air Force linked to the Air Technical Intelligence Center under Air Research and Development Command (ARDC) at Wright-Patterson Air Force Base in Ohio. Headquartered on "Security Hill," the USAFSS complex at Kelly evolved into the Air Force Intelligence Command (today's Air Intelligence Agency). Kelly also hosted the 182nd Fighter-Interceptor Squadron (FIS) of the Air National Guard (ANG) as of about 1956, in support of the air defense mission of Air Defense Command (ADC)—but without a compound of standard alert facilities. Beginning in 1962, the installation took on a series of missions for the Houston Manned Space Center and nearby Brooks Air Force Base for the National Aeronautics and Space Administration (NASA). Kelly sustained the NASA missions until the end of the Cold War.

Primary Missions

The primary Cold War missions at Kelly Air Force Base included:

- logistics support for early atomic weapons testing;

- storage, distribution, and maintenance of nuclear weapons, weapons components, kits, and kit components (within the Directorate of Special Weapons);
- cradle-to-grave storage and distribution responsibilities for nuclear training weapons, test, and handling equipment (through the Nuclear Ordnance Commodity Management Support Plan);
- continuing development of Air Force chemical, biological, and nuclear weapons decontamination procedures for international application;
- storage of defoliant herbicides, including Agents White, Blue, and Orange;
- overhaul of the B-26 and B-29 for service in the Korean War;
- prime maintenance and supply responsibilities for the B-36, B-58, B-70, C-45, C-131, F-102, F-106, L-5, L-23, T-29, and T-34;
- design of very early engine and aircraft nose shelters, as well as maintenance workstands, for the B-36 and XC-99;
- modification and Inspection and Repair as Necessary (IRAN) for the B-47;
- a Specialized Repair Activity (SRA) for the B-52 and the C-5, followed by modification / IRAN assignments for both aircraft;
- lend-lease transfer of aircraft to foreign governments;
- foreign officer training in aircraft supply and maintenance;
- operation of a maintenance training school for the command;
- an operational test program for large-sized transport aircraft (the XC-99 / Project AMC [Air Materiel Command] / SC [super cargo] -175);
- overhaul of aircraft engines;
- maintenance and logistics support for the Vietnam War;
- management of the hydrazine family of missile fuels; and,
- procurement and commodity management of the Department of Defense working dog program.

Tenant Organization Missions

Key Air Force and ANG tenant missions hosted at Kelly were:

- the USAFSS; and,
- an ANG fighter-interceptor squadron.

Kelly also supported NASA as of 1962 through:

- logistics assignments for Air Force Systems Command (AFSC) aircraft supplied to the Houston Manned Space Center for proficiency flying;
- manufacture of Apollo capsule trainers;
- fabrication of human and animal "transverse G (gravity)" couches for centrifuge testing at the Aerospace Medical Center at Brooks;
- liquid propellant management responsibility, including supply, as of 1966; and,
- repair and maintenance of the Super Guppy.

Chronology

Kelly's chief mission of the Cold War, that of an Air Materiel Command / AFLC depot, was substantially in place as of the 1920s.[1] Land acquisition and development at Kelly was particularly complex through the middle 1950s (Plate 94). In March 1921, the Army had combined two World War I depots at Kelly, known as "Kelly 1" (1916) and "Kelly 2" (1917), into the San Antonio Air

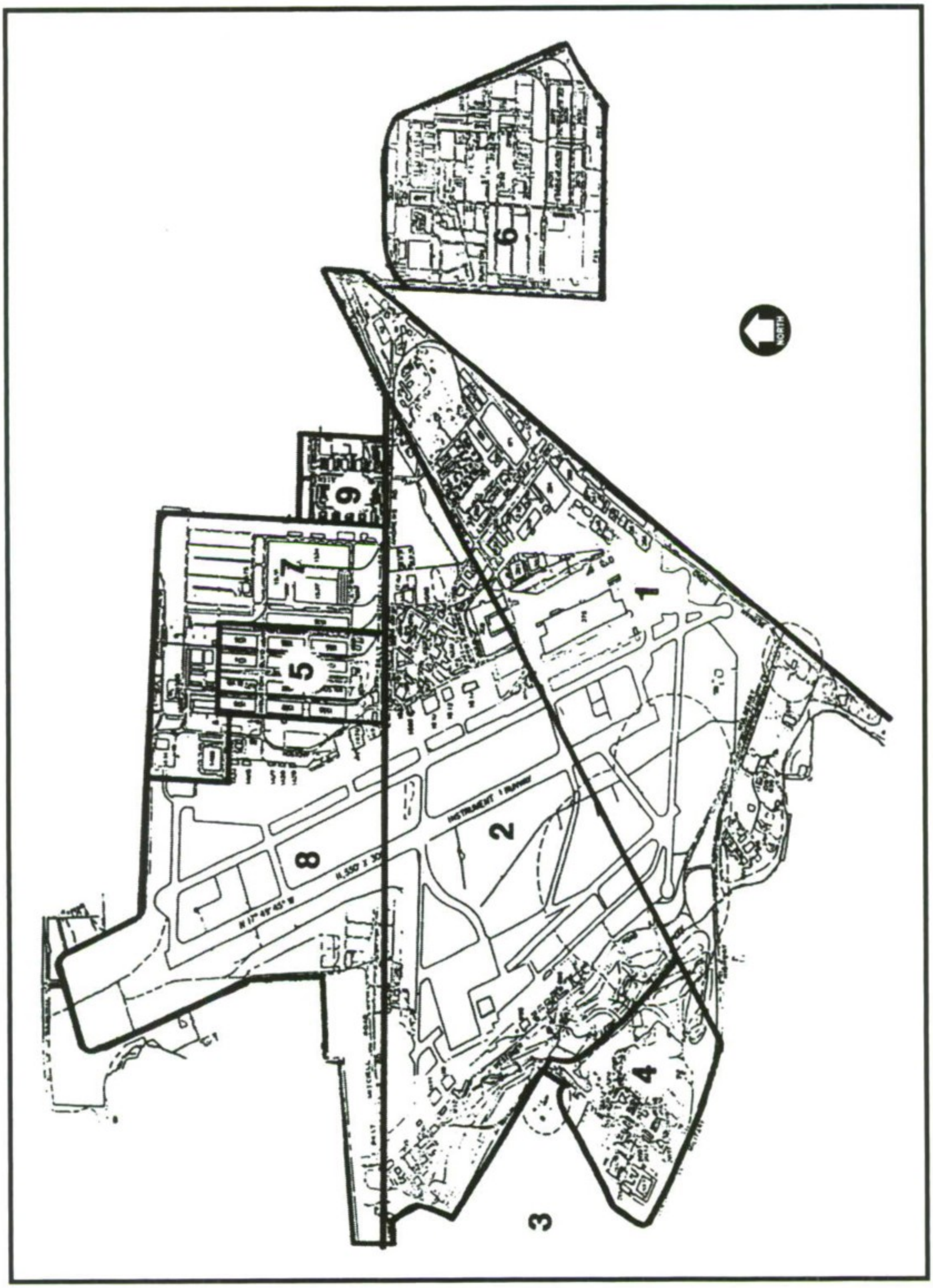

Plate 94: Land Purchases and Airfields at Kelly Air Force Base. 1: "Kelly 1." 2: "Kelly 2." 3: Originally a bombing range for Kelly Field (later ceded to Lackland). 4: Security Hill. 5: Warehouse area added in 1943. 6: Depot area added in 1945. 7: Special Weapons Directorate and new supply warehouses area added in 1954. 8: Land for runway extensions in the middle 1950s. 9: Housing area added in 1960. Adapted from *A Brief History of Historical Sites and Structures on Kelly Air Force Base*, April 1993.

Intermediate Depot. The two installations of the teens were each located in distinct areas of the larger Kelly Field. Kelly 1 had hosted a general supply mission, and was sometimes referenced as Duncan Field. From 1927 into World War II, Kelly was known as the San Antonio Air Depot. Permanent construction dated to the late 1930s, primarily for the Advanced Flying School sited at "Kelly 2". Kelly's pilot training missions were interwoven with similar endeavors at the neighboring Air Corps installations of Randolph (where primary and basic training occurred) and Brooks Fields (which became a subpost to Kelly). Warehousing at "Kelly 1" also expanded during World War II and included a 396- by 640-foot structure (Building 171) designed by Detroit architect Albert Kahn.[2] By January 1943, Kelly Field featured four runways, of 5,518-, 5,908-, 6,834-, and 7,343-foot lengths—adding a fifth runway of 5,350 feet in 1945. The 7,343-foot runway was 150 feet wide. Air Technical Service Command (the predecessor of Air Materiel Command) planned this runway for early use by the heavier bombers of late World War II.

Two hangars of the late 1930s and early 1940s were particularly important additions at Kelly. A double Air Transport Squadron Hangar was located on "Kelly 2" directly to the southwest of the warehousing area. Originally designed in 1940 by Albert Kahn, this hangar went through a series of sophisticated improvements during the early 1940s. Fred N. Severud, an internationally prominent Norwegian engineer with a consulting practice in New York City, created the doubled version of the hangar. The modified hangar was formally titled an Operations - Transport Squadron and Flight Test Hangar. Severud designed a final version of the structure, the Hangar (Expansible) for V.H.B. [very heavy bomber] Aircraft in 1944-1945. Only a few examples of the Hangar (Expansible) for V.H.B. Aircraft were built (at Eglin in Florida, and at Norton and Travis Air Force Bases in California). While the hangar of 1944-1945 was specifically designed for the B-36 (see Volume I, Part II, and, Volume II, Chapters 4 and 6), the transitional Operations - Transport Squadron and Flight Test Hangar was also marginally able to handle the aircraft. A number of Air Materiel Command depots of 1940-1944 had either an Air Transport Squadron Hangar (for example, Hill Field in Utah) or an Operations - Transport Squadron and Flight Test Hangar (for example, Griffiss, Robins, Tinker, and Patterson Fields in New York, Georgia, Oklahoma, and Ohio, respectively) (see Plate 103) (see Volume II, Chapters 6, 11, 12, 13, and 14). The SAAMA at Kelly used one half of its Operations - Transport Squadron and Flight Test Hangar for overhaul of the XC-99, the experimental cargo version of the B-36 assigned to the base in July 1949 (see below). AFLC heavily modified the Operations - Transport Squadron and Flight Test Hangar at Kelly (Building 365) as a painting and cleaning hangar for the C-5 in the early 1970s[3] (see Plate 103) (see below). To the northwest of the Operations - Transport Squadron and Flight Test Hangar was a tied steel arch maintenance and repair hangar designed by the Army Quartermaster Corps (formally known as an Airplane Repair Building) (Building 1610). Erected at Kelly during 1939-1940, the Airplane Repair Building was often constructed at the same installations that had Air Transport Squadron Hangars or Operations - Transport Squadron and Flight Test Hangars. Design of the Airplane Repair Building dates to 1938. Although designed very early, the hangar could accommodate most of the larger bombers of the Cold War. The hangar featured a 275-foot clearspan and varied in length from 190 to 250 feet (about 235 feet at Kelly). Its aircraft doors were 37 feet high and 250 feet across, and included a center lift door that made it possible for the hangar to accommodate aircraft with tail heights of up to about 50 feet. The hangar often had side and / or rear shops (as at Kelly). The Army Air Corps and Army Air Forces erected the Airplane Repair Building at multiple installations during 1938-1944, sometimes as a single structure, and at other times doubled, tripled, or quadrupled (see Volume II, Chapters 6, 10, 11, 12, 13, and 14). The most common occurrence of the Airplane Repair Building was as two pair of hangars constructed back to back with center shops. This configuration was also the mature version of the hangar, erected well into World War II. At Kelly, the Army Air Corps erected only a single hangar.[4]

After an initial phase-down upon conclusion of the war in the Pacific, Kelly Field became involved in early events of the Cold War. As was also true for the installations of Eglin (in Florida), Kirtland (in

New Mexico), and McClellan (in California), Kelly participated in Operation Crossroads, the first atomic bomb test project of the American government post-World War II. Crossroads was in planning by late summer 1945. Live detonations took place the next year during June and July at the Pacific Proving Ground in the Marshall Islands (see Volume II, Chapters 4, 8, and 10). Headquarters Air Technical Service Command / Air Materiel Command assigned Kelly the responsibility of converting B-17s to remotely controlled drone aircraft. Personnel at the base also overhauled B-17s as control aircraft for the project.[5] The Army Air Forces planned to fly the pilotless B-17 drones through the post-detonation radioactive atmosphere to take samples. This approach lessened the dangers to airmen. The control B-17s (mothers) directed the B-17 drones (children). (The "mother" and "child" terminology derived from that used for World War II bombs. A single large "mother" bomb, for example, was actually comprised of many individual smaller "child" bomblets.) Efforts at Kelly for Operation Crossroads were concentrated in February and March 1946. After base personnel had converted the B-17s to drone and control aircraft, Air Materiel Command transferred the mother-child pairs to Eglin Field for test flights and crew training by the 1st Experimental Guided Missiles Group (see Volume II, Chapter 4). Pilots from Eglin also flew the aircraft during the actual atmospheric tests in the Marshall Islands in the summer. The 1st Experimental Guided Missiles Group ran other tests and demonstrations with the B-17 drones, reactivating 15 B-17 control aircraft and 15 B-17 drones during 1948 for Operation Sandstone.[6]

Like Crossroads in 1946, Sandstone took place at the Pacific Proving Ground. For that test, Air Materiel Command assigned Kelly the task of modifying B-29s to carry the atomic bomb. Personnel at Kelly augmented the bomb bays of B-29s with a feature nicknamed a "saddletree." Strategic Air Command (SAC) also required that its B-29s be retrofitted with saddletrees for war readiness in the new era.[7] By 1950, Kelly was also actively involved in early procedures for the disposal of radioactive waste. Three years later, Kelly had completely filled its first radioactive waste well on base, sealing it with a cement cap and drilling a new well adjacent to it for the disposal of toxic materials. Reporting personnel evaluated the method of disposal as "satisfactory" and "operating at a very nominal cost."[8] As of 1954, the SAAMA at Kelly also acquired the mission to isolate, store, and decontaminate radioactive engines from the B-36. By this date, the B-36 was the aircraft that flew the atomic and thermonuclear bomb drops at the Nevada Proving Ground (later, Nevada Test Site). The Nevada location was in the vicinity of Nellis Air Force Base, but was run by the Atomic Energy Commission (AEC) (later, the Department of Energy). Indian Springs Air Force Base, an ARDC installation, supported the Nevada Proving Ground and was at times a subinstallation of Nellis. Pilots typically flew B-36s to the test drops at the Nevada Proving Ground after preparations at Kirtland Air Force Base by the 4925th Special Weapons Group (as of mid-1950, the 4925th Test Group [Atomic]) (see Volume II, Chapter 8). The B-36 also gathered atmospheric samples after the blasts, a test activity that resulted in contaminated engines. The Convair B-36 plant at Carswell Air Force Base in Fort Worth discovered the radioactive engines problem (see Volume II, Chapter 15), and Kelly received its new mission. Air Materiel Command built a special facility to handle the decontamination procedures.[9]

The SAAMA's role in Air Force decontamination efforts expanded as the Cold War moved forward. In February 1955, Kelly hosted a Radiological Monitor Instructors course for representatives from each Air Force depot and Air Materiel Area (AMA). Course participants were then to act as instructors for further courses at their respective bases. To gain working experience with decontamination issues for special weapons, SAAMA personnel attended nuclear tests at the Nevada Proving Ground. For some of these tests, Kelly personnel decontaminated radioactive aircraft on site at Indian Springs Air Force Base. Men from Kelly also observed "bacteriological warfare" tests run by the Air Force Armament Center (AFAC) at Eglin. The Eglin tests took place both on the ranges surrounding that base and at the Army's Dugway Proving Ground in Utah (see Volume I, Part III, and, Volume II, Chapters 4 and 6).[10] Kelly received the overall responsibility for preparing nuclear

(radiological), chemical, and biological decontamination procedures across the Air Force, including the task of developing project-specific plans when required. One example of this type of need was the 1968 crash of a B-52 near Thule Air Base, Greenland. The B-52 was loaded with unarmed nuclear bombs. The bombs did not detonate, but did leave radioactive debris at the accident site. The SAAMA extracted the debris and shipped containers of contaminated waste off site under the guidance of the AEC.[11] A similar accident had occurred over the coast of Spain two years earlier and had required the removal of 1,500 tons of contaminated topsoil and plant material (see Volume I, Part I). Two other missions at Kelly related to toxic materials focused on issues of specialized storage and supply. The SAAMA was responsible for missile fuels for NASA's spaceflight program and for the Vietnam War herbicides of Agents Blue, White, and Orange. Both programs ran through the SAAMA's Directorate of Aerospace Fuels established in 1966. The NASA fuel mission remained operational through the remainder of the Cold War, while the herbicide mission, concentrated on Agent Orange, concluded in the late 1970s with disposal of the agent on the Dutch incinerator ship *Vulcanus*. Kelly was one of four international locations storing Agent Orange for the American government, with the other facilities located in Gulfport, Mississippi; at Eglin; and, on Johnston Island in the Pacific.[12]

Simultaneously with its acquisition of the Crossroads project in 1945, Kelly had also begun to prepare for receipt of the B-36. Air Materiel Command had initiated planning toward major infrastructural changes for the bomber, as early as 1944 while the aircraft was still in development. The B-36 was known at first as a very, very heavy bomber (VVHB) and then as the VHB replacing the B-29.[13] Selected research and development (R&D) bases within the command, as well as designated depots and Convair's production plant site in Fort Worth, all needed to address the challenges posed by the bomber. First and foremost was provision for new runways, or interim improvement of existing runways. At Kelly the 7,343-foot runway of 1942, while short for the B-36, had been engineered for heavy bombers. The runway sufficed for landing the B-36 until completion of an 11,550-foot runway in 1955-1956 (see Plate 94).[14] By late 1944, Air Technical Service Command anticipated that Kelly might be the depot to receive primary responsibility for modification, repair, and maintenance of the B-36. Kelly's location to the southwest of the Convair plant in Fort Worth (Air Force Plant [AFP] 4) set the stage for the role of the base. At that time, the command proposed a super-large, production-line overhaul hangar for the heaviest bombers to come—a structure that was realized at the base during 1952-1956 through the erection of Building 375 (see Plate 98). As of 1947, personnel at Kelly began construction of buildup stands for the Pratt & Whitney R4360 engine of the B-36. In this year, the installation envisioned its future production-line hangar as 1,200 feet long and 500 feet wide, with four sliding doors 90 feet high accessing the structure at each end. The overhaul hangar was to feature three stories of offices, shops, and supply stations along the center interior.[15] In late August 1948, the first B-36 landed at Kelly for bomb bay door repairs. Several more B-36 assignments followed in 1949. The initial primary overhaul responsibility for the B-36 had actually gone to the Oklahoma City AMA at Tinker Air Force Base, but by mid-1951 Air Materiel Command designated Kelly a Specialized Repair Depot for the bomber.[16]

From 1946 into 1951, overhaul, maintenance, and modifications for aircraft at Kelly was an outdoor project relying on a production-line methodology fostered by Headquarters Air Materiel Command to modernize the work (Volume I, Part II). San Antonio's mild climate made the system possible, with aircraft lined up in double parallel rows for a mile's length from the late 1930s Airplane Repair Building (Building 1610) to the site of the anticipated overhaul hangar of the middle 1950s (Building 375). To accommodate efficiency, the facilities ran overtime hours and were lit at night.[17] Nonetheless, personnel could not accomplish all maintenance without cover from wind, rain, and intense sun. The very large size of the B-36 exacerbated the growing challenges of 24-hour-a-day, production-line overhaul outdoors. Personnel at other Air Force warm-weather installations receiving the B-29, B-50 (a modified B-29), and B-36 moved portable docks into place at each engine, or over

each aircraft wing, for routine maintenance. Such improvised shelter was also the norm for bases with very harsh winter weather conditions, but at these installations the climate made a more permanent dock imperative. The SAAMA had even designed one such dock in late 1949, called an Arctic workstand, for the B-36. This temporary structure was 24 feet high, 17.5 feet wide, and 22 feet deep—described as "having the cubic area of a small five-room house." It resembled the docks of World War II in its metal framing and exterior canvas covering. Gasoline heated, the small dock sheltered up to six mechanics while they worked on individual B-36 propellers and engines.[18] The simple docks offered a transitional solution by 1950-1951, but did not offer a true workspace sheltered from the elements. Several variations of dock existed, possibly developed at a base level and shared among bases as standard structures thereafter.

The phenomenon was short-lived, replaced by full-scale nose docks for the B-36 and B-47 in April 1951. Danish immigrant engineer Peter A. Strobel designed the two docks for manufacture by Luria Engineering (also of New York) (see Volume II, Chapter 5). These remarkable docks encased the wings and forward body of the planes. For the B-36, the Luria dock was very large and was erected at key SAC bases of the very early 1950s. For the B-47, the dock imitated the swept-wing shape of the bomber. Today, Luria B-36 docks are very rare (with the best remaining example at Ellsworth Air Force Base in South Dakota). The B-47 docks no longer exist at any known location in the continental United States. A standard Luria multipurpose dock followed by 1953-1956. A dock for the B-52 completed the series.[19] Maintenance personnel at Kelly initially set up B-36 work in the outdoors production-line area. To enhance all-weather maintenance work, the SAAMA contracted for 10 pair of portable wing docks[20] from the East Texas Engineering Company in 1951. Supplied at a cost of $353,000 under contract 41 (608) 6196, the docks appear to be unique within the Air Force—erected only at Kelly.[21] These docks were different from the simple docks of the same period at Biggs, Walker, and Carswell Air Force Bases in the Texas-New Mexico region, and were also distinct from the full-scale nose docks designed by Peter Strobel for Luria the same year. Movable nose shelters, designed and fabricated at Kelly, augmented the East Texas Engineering Company docks.

The B-36 docks at Kelly were much more substantial structures than other interim wing docks of the 1950-1951 period. When closed, the docks nearly completely sheathed the triple propeller-driven engines on each wing of the earliest B-36s (Plates 95-96). Personnel at Kelly constructed the large docks, which operated like the counterbalanced movable sections of a bascule bridge.

> A complete dock consists of four parts for easy mobility and if it has to be moved to another part of the base, an especially designed dolly will tow each section separately. Roof and front wall are an integral part, actuated by an electric motor which raises both simultaneously, providing an opening for an aircraft to get in and out. The roof is supported by the cantilever principle and a concrete block, weighing approximately 10,000 pounds, is used as a counter-weight for opening and closing the docks. These docks are covered with heat-reflecting, corrugated aluminum sheeting attached to a structural steel framework with a blanket of Fiberglas one and one-half inches thick.[22]

The B-36 wing docks, each with an aircraft nose shelter, created an impressive interim overhaul facility. By about May 1951, B-36s were arriving at the depot in greater numbers, and the docks were a stopgap measure to improve repair and maintenance on the unwieldy bomber. Kelly had first established a B-36 work area near the Operations - Transport Squadron and Flight Test Hangar (Building 365), but temporarily moved it to the west of Building 1610 (the Airplane Repair

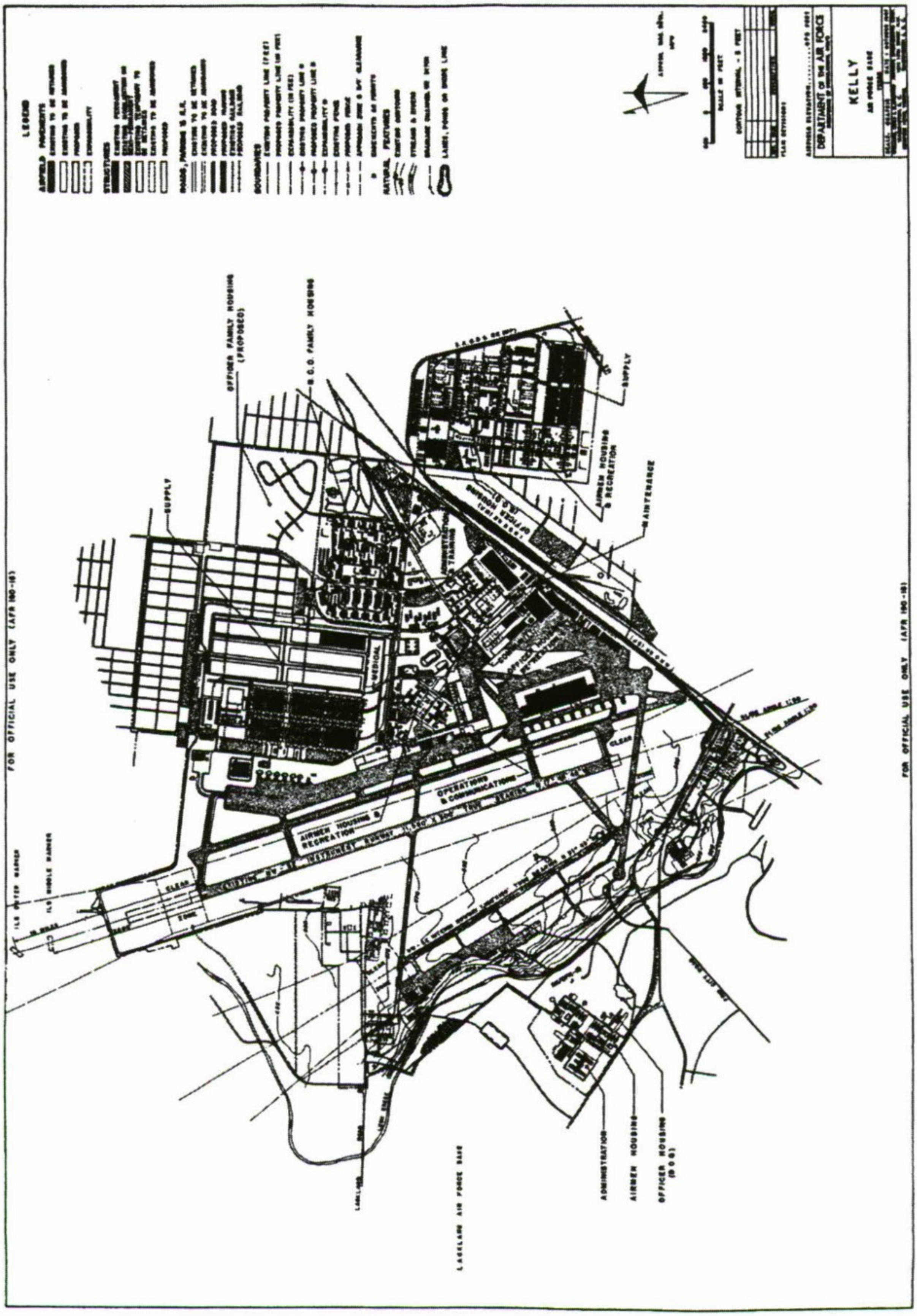

Plate 97: Directorate of Installations, Headquarters United States Air Force. Master Plan for Kelly Air Force Base, October 1957. Collection of K.J. Weitze.

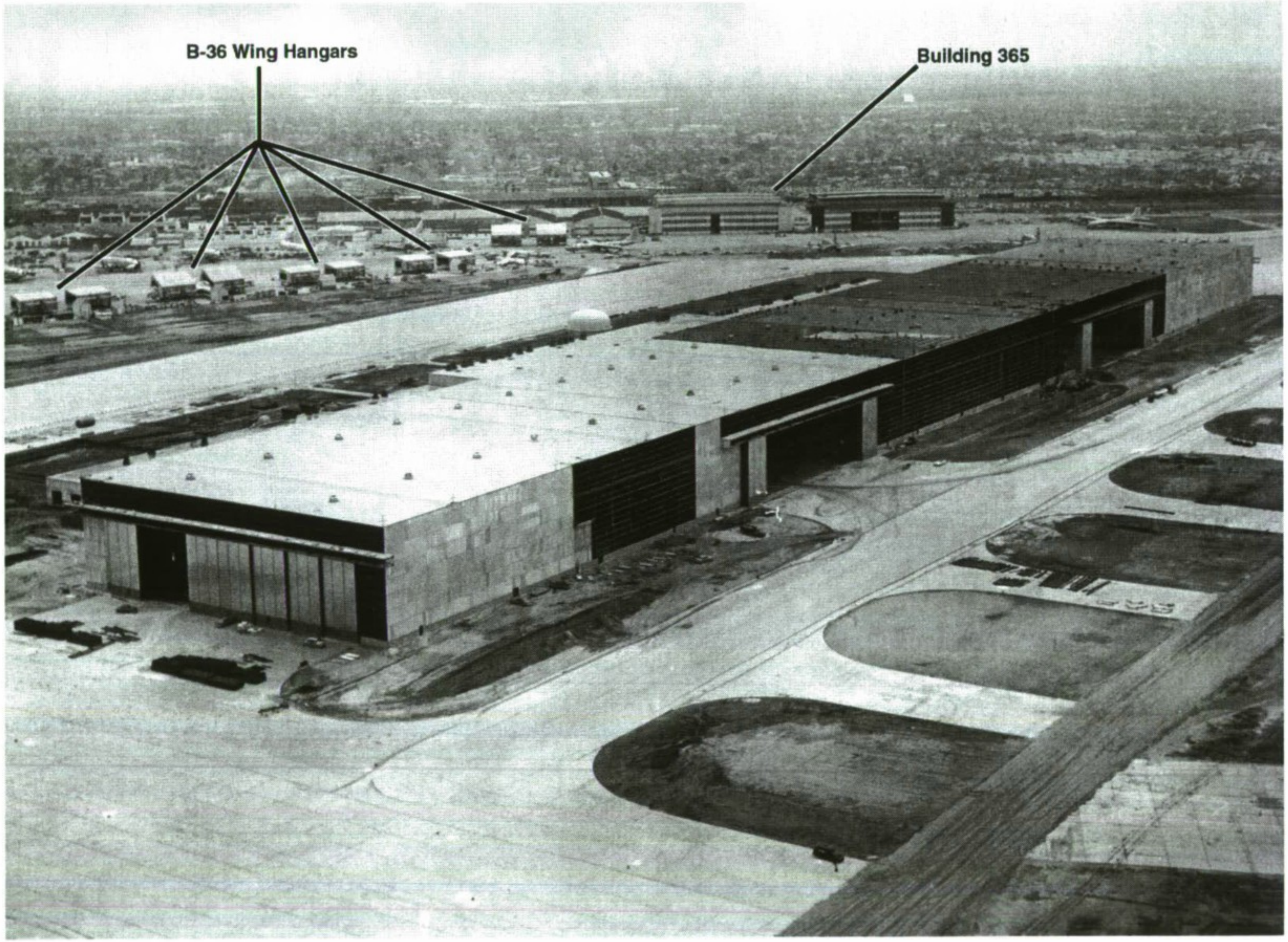

Plate 98: Kuljian Corporation. Aircraft Repair Hangar (Building 375), Kelly Air Force Base, 1952-1953. Other hangars and B-36 wing docks in background. View of February 1955. In *History of San Antonio Air Materiel Area 1 July – 31 December 1954.* Annotations added.

the interconnections between certain aircraft and their primary command. The XC-99 had the mission of supplying SAC's bomber bases, where appropriate runways, hangars, and nose docks existed. Air Materiel Command used the XC-99 to airlift hundreds of thousands of pounds of supplies to overseas bases during the 1950s. As of 1954, Kelly's maintenance responsibilities for the XC-99 shifted from those for an experimental aircraft to routine needs, under the IRAN depot regime. The XC-99 reached an unflyable condition in March 1957, and by July the same year Air Materiel Command declared the aircraft surplus to its needs.[30] When Kelly closed in 2001, the XC-99 was still present at the installation—parked as an artifact of the past.

While the elaborate interim overhaul for the B-36 and XC-99 relied upon open-air maintenance, reuse of a World War II hangar (Building 365), and the wing docks of 1951, plans went forward for the pass-through overhaul hangar that the command had envisioned as early as 1944. Kuljian Corporation in Philadelphia designed and engineered the very large hangar (Building 375) in 1952. The firm had previously designed the B-36 double-cantilever hangar of 1951[31] (with that hangar also linked to a patented conceptual design of 1944: see Volume I, Parts II and III). Under construction in 1953, Building 375 was formally titled the Kelly Aircraft Repair Hangar. The structure was 2,000 feet long, 300 feet wide, and 91 feet high. It included attached shops of 1,650- by 250-foot dimensions along its east façade (see Plate 98). More importantly, eight-panel openings on the northern and southern ends of the hangar were 250 feet across and 60 feet high. These dimensions were very similar, or identical, to those of the double-cantilever hangar that immediately preceded the Kelly Aircraft Repair Hangar. The western façade faced 10 right-angled parking stubs and also featured two eight-panel doors in the second and fourth bays. The structure was modular and partially used a double-cantilever system. Five independent units, each 400 feet long, comprised the hangar, in a system that "offered economy, alleviated thermal and settlement stresses, and provided future expansion in identical bays already designed and detailed." The key elements of each 400-foot module were a pair double-hinged, rigid-frame, double-cantilever steel trusses spanning the 300-foot width of the structure. Each truss was 24 feet deep and spaced 36 feet apart center to center (10 trusses total for the entire hangar). Ten additional 250-foot span trusses perpendicularly framed into the paired double-cantilever trusses of each 400-foot module (50 trusses total for the entire hangar). The 250-foot trusses cantilevered out an additional 74 feet at each module end. In short, Kuljian had arranged five "hangars," each 300 feet wide by 400 feet deep, end to end to create the oversized structure. The design allowed for future lengthening should that become desirable.[32] The American Bridge Division of United States Steel in Pittsburgh fabricated and erected the steelwork.[33] The underlying apron for the hangar, like the required runways for the B-36, was heavy duty and featured reinforced concrete 16 inches deep. Kuljian designed the overhaul hangar at Kelly to accommodate 10 B-36s at one time.[34] Similar to many of the double-cantilever hangars designed specifically for the B-36, the overhaul hangar at Kelly became a general-purpose maintenance facility for very large aircraft. Its lengthy construction time, coupled with new missions for the depot, did not allow the SAAMA to use Building 375 for the B-36. A modification / IRAN mission for the B-47 in late 1956 inaugurated the hangar, just as B-36 and XC-99 activities at the base began to phase down.[35] Air Materiel Command had planned to erect a second identical Kuljian Aircraft Repair Hangar at Robins Air Force Base in Georgia as of late 1952, but instead built only the hangar at Kelly (see Volume II, Chapter 11). Building 375 could handle 14 B-52s simultaneously, and later six C-5s.

Yet another major early Cold War mission at the installation evolved from the movement of the headquarters for the USAFSS from nearby Brooks to permanent facilities at Kelly. The USAFSS derived from the Army Security Service, headquartered in Arlington, Virginia. The Air Force had established its own, independent security service in 1947, tied to the Directorate of Intelligence at Headquarters Air Force in Washington, D.C. The Air Force security service was initially collocated with the Army Security Service in Arlington. Headquarters Air Force moved the Air Force security service unit from the Army site in Virginia to Brooks in April 1949. The USAFSS was an

intelligence agency that later evolved into the Electronic Security Command (1979), and subsequently to the Air Force Intelligence Command at the close of the Cold War in the autumn of 1991 (today's Air Intelligence Agency).[36] Known at Kelly as West Kelly, or Security Hill, the USAFSS area was fully segregated from other functions on the base. Kelly had acquired the land for Security Hill in the early 1940s as a military training site (see Plate 94). Construction for the USAFSS was underway in 1951 (see Plate 97). At Brooks, the USAFSS occupied a World War II hospital complex and its barracks while the agency awaited decisions about its permanent infrastructure at Kelly (see Volume II, Chapter 2).[37] By mid-1952, the Headquarters USAFSS (Building 2000) at Kelly was 40 percent completed. At the close of the year, construction for Building 2000 reached 83 percent, with eight barracks (Buildings 2003-2006 and 2009-2012), a mess hall (Building 2008), and a warehouse (Building 2028) also underway. A second mess hall (Building 2007) for the complex followed in 1953, as did four more airmen dormitories (Buildings 2013, 2015, 2018, and 2020) (Plate 99). Building 2007 is demolished today.

The USAFSS approached the construction of its hilltop security headquarters as a task to be completed as quickly as possible. The agency used available, "standard" Air Force designs for each major building (administrative headquarters, dormitories, mess hall, and warehouse). For example, Building 2000 is derived from the Air Force "Headquarters" series of 1951, a multipurpose group of buildings designs for different types and sizes of administration structures.[38] This series bears an identifying drawing number of "30-02-xx." For Building 2000 at Kelly, its identifier is 30-02-01, the

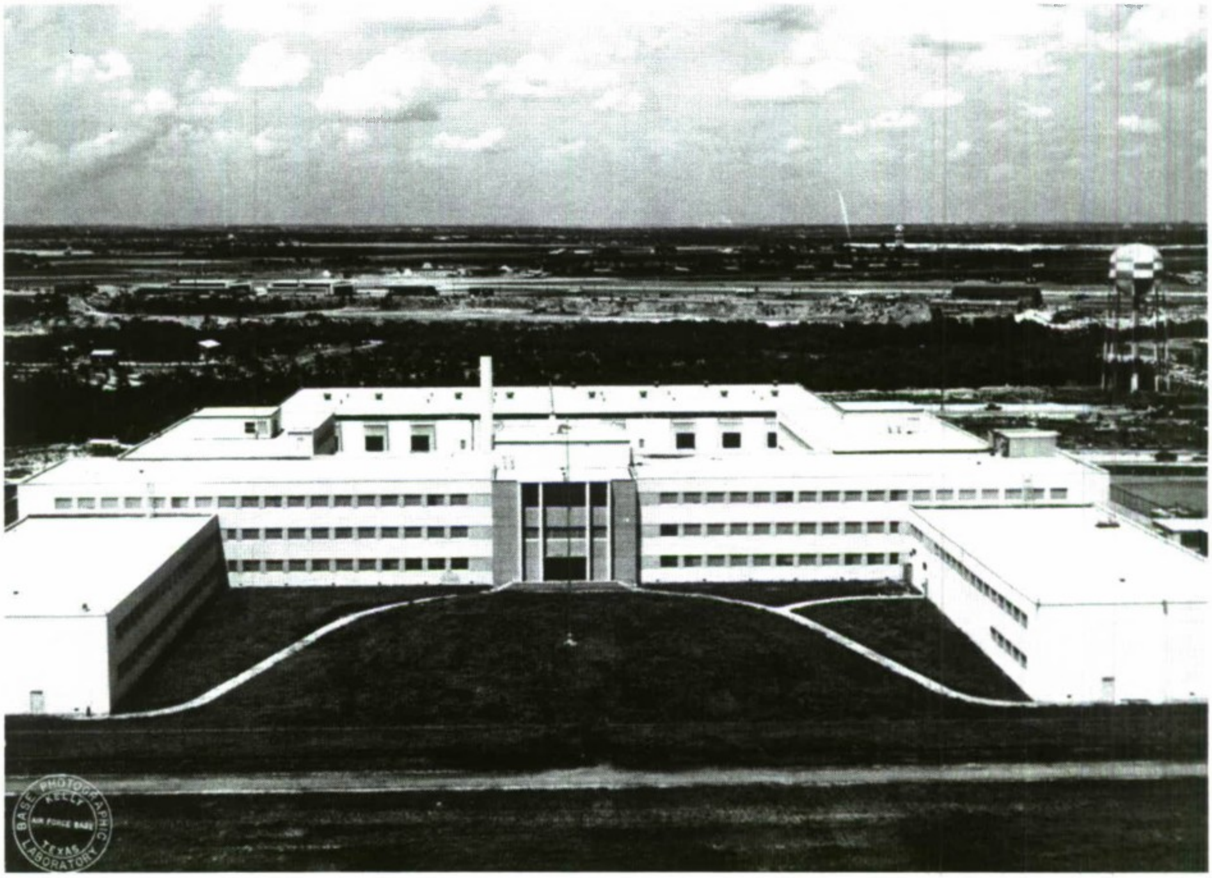

Plate 99: United States Air Force Security Services Headquarters (Building 2000), Kelly Air Force Base, 1951. View of 1953. In *History of San Antonio Air Materiel Area 1 July – 31 December 1953.*

baseline design in the group. While the drawings for Building 2000 bear the name of a local San Antonio architectural-engineering firm (Phelps, Dewees & Simmons) in the title block, this firm was only responsible for the construction management and site adaptation of an already existing design.[39] The 12 dormitories were all derived from the standard 1951 Air Force design of Frank Grad & Sons of Newark, New Jersey. Frank Grad & Sons' dormitories went up at many Air Force bases during the early 1950s, as utilitarian barracks and as ready crew quarters at ADC alert areas. The mess hall was also a design of Frank Grad & Sons from 1951 for a "Mess and Administration Building for 500 Airmen."[40] Frank Grad & Sons dormitories and mess halls were usually configured as grouped clusters, as for Security Hill at Kelly. Another example of the standard Frank Grad & Sons dormitory-and-mess hall design is a group of barracks at Eglin from this same period. At Kelly and Eglin, the dormitory constructed was the "I" barrack, so-named due to its shape. The Eglin dormitories went up during 1952-1954 as two groups of four barracks, each with a central mess hall.[41] The original plan for Security Hill in 1951 featured a similar arrangement: two clusters of dormitories facing centered mess halls. The intent was for 10 dormitories to bracket a mess hall in regular rows, with 20 dormitories and two mess halls the total number of structures. The USAFSS scaled back this plan to 12 dormitories and placed the mess halls off center in relationship to them.[42] The USAFSS moved from Brooks to Kelly in August 1953 with a personnel strength of 2,500 (300 of whom were civilians). The security agency was the largest tenant at the base.[43] The USAFSS processed and analyzed intelligence information gathered by personnel in the field and by electronic equipment of many types.

Kelly's role in nuclear weapons support also continued to expand during the early 1950s. By 1950, Kelly neighbored one of the six main stockpile sites for American atomic (and later, thermonuclear) bombs. The sites were alpha-coded and given "base" names. The overall program included what were known as National Storage Sites (NSSs) and Operational Storage Sites (OSSs). Construction began in 1946 and continued into the late 1950s. Headquarters Air Materiel Command had program responsibility for Air Force sites until takeover of the agency's NSSs and OSSs by SAC (see Volume I, Part II). Sites A – C were built in 1947-1949 as Manzano Base (Site A at Kirtland) (see Volume I, Part II, and, Volume II, Chapter 8), Killeen Base (Site B at Fort Hood, Texas), and Clarksville Base (Site C at Fort Campbell, Kentucky). By the middle 1950s, the program expanded to include the OSSs. The total number of stockpile and operational storage compounds was 13 in the continental United States.[44] Sandia Base (Sandia National Laboratories today) orchestrated the planning for the special storage sites as Project Water Supply, working with the AEC and the Department of Defense. The storage sites had somewhat differing roles, with infrastructure maturing from protective construction inside literal mountainsides at Kirtland, Fort Hood, and Fort Campbell, to aboveground igloos and associated structures. Black & Veatch of Kansas City designed all of the complexes. The firm had begun this type of specialty engineering for Los Alamos immediately after World War II. Medina Base, Site King (K) in San Antonio, was an NSS that stored weapons assemblies and nuclear materiel. Site selection for Medina Base dated to 1951, with the SAAMA directly involved as of 1954. Located six miles west of Kelly, Medina Base signed an operating agreement with the installation in late 1955 for the "Handling of Restricted Data Materiel between Kelly and Medina Base." Kelly provided airfield services to transfer materiel to and from Medina Base using aircraft from Kelly, including "source and / or fissionable" materiel. Air Materiel Command constructed an access road between the main gate of Medina Base and a western gate of Kelly for the mission.[45] The total American stockpile of atomic bombs jumped from 110 in 1948 to 298 by June 1950, with stockpiles reaching 832 bombs by the end of 1952. In 1955, the United States maintained an inventory of 3,057 nuclear (atomic and thermonuclear) bombs.[46]

Special weapons storage responsibilities tied to Medina Base and to the Armed Forces Special Weapons Project (AFSWP) had arrived at Kelly in 1952 through the transfer of the 2837th Specialized

Depot Group from Kirtland to Kelly. Beginning in late 1950, the AFSWP had initiated training of personnel within Air Materiel Command through Sandia, to take over management of the main stockpile sites maintained by the Air Force and the Air Force OSSs. Headquarters Air Materiel Command also assigned the SAAMA responsibility for the management of the Kirtland Air Force Specialized Depot. The command simultaneously issued a directive for the establishment of "Specialized Depots," generally. The 2837th Specialized Depot Group at Kirtland (1950-1952), and subsequently at Kelly, had the mission of "providing concentrated storage, distribution, and maintenance of special weapons, weapon components, kits, kit components, and training equipment." In January 1953, Headquarters Air Materiel Command created a Directorate of Special Weapons at Kelly to further orchestrate the new nuclear weapons assignment. The Directorate of Special Weapons evolved into a complex organization, with international responsibilities for logistics management of the Air Force Nuclear Ordnance Program. Ordnance included the nuclear warheads of the Atlas, Titan, Minuteman, and Peacekeeper intercontinental ballistic missiles (ICBMs), for example. The Directorate's efforts featured "nuclear weapons' control, nuclear safety, nuclear security, nuclear weapons' trainers, retardation devices, technical data, test programs, and plans." As of the early 1970s, the Directorate of Special Weapons had set up the Nuclear Ordnance Logistics System, a computerized data base installed on a Cyber 73 computer. The Control Data Corporation Cyber 70 series was a supercomputer capable of processing many calculations extremely quickly, as needed for nuclear weapons development and for complex missile tracking in air defense. The Cobra Dane large phased-array radar in the Aleutians Islands off the coast of the Soviet Union (of this same period), as well as the Perimeter Acquisition Vehicle Entry Phased Array Warning System (PAVE PAWS) radars of the late 1970s and middle 1980s, all featured Cyber computers.[47]

The Directorate of Special Weapons was primarily a logistics management unit that handled nuclear ordnance as a commodity and became the Air Force's single point of first contact. The Directorate had substantial training responsibilities for working with nuclear weapons. It also had a cradle-to-the-grave assignment for atomic training weapons, and for test and handling equipment.[48] The Air Force purchased additional land at Kelly for the Directorate of Special Weapons mission in 1954[49] (see Plate 94). For storage of the training weapons (and test and handling equipment), Air Materiel Command built a new 160,000 square-foot warehouse at Kelly (Building 1420). The warehouse was one of two "Special AMC" Warehouses erected at Kelly in 1954-1956, both part of a much more comprehensive warehouse program within Air Materiel Command during 1951-1957. The Special AMC Warehouse was a 1952 design of the Baltimore firm of L.P. Kooken. The warehouse utilized rigid-frame reinforced concrete construction, cast in place with continuous girders. The final design offered two framing systems, three variant wall panel choices, and two roof slab types. Highly modular, the warehouse was also so experimental that it suffered partial failures in several of the 20 Air Materiel Command depot locations where it was built and underwent a "girder structural study" at Kelly in late 1955. Ammann & Whitney, a preeminent engineering firm in New York, carried out the study across the Air Materiel Command depots affected, also devising the structural strengthening required to fix the problem. At Kelly, workmen installed steel bands around the girders after a delay of 18 months while awaiting the $460,000 in needed funding for the project. The two warehouses at Kelly were ready for occupancy in early 1957[50] (see Volume I, Part II, and Volume II, Chapters 6, 10, 11, 12, and 13).

The warehouse used by the Directorate of Special Weapons was in no way a hardened structure, nor one similar to the weapons storage facilities erected at neighboring Medina Base. Instead, Building 1420 was an efficient warehouse for storing training weapons, test equipment, and other nonexplosive weapons items. Building 1420 continued to function in its original mission of supporting the Air Force nuclear weapons program for much of the Cold War. Three directorates occupied the warehouse: Special Weapons, Distribution, and Maintenance. Building 1420 still stored training

components, transport containers, and spare parts for the nonexplosive systems of nuclear bombs and missile warheads in 1983. Warehoused items were small, on-the-shelf units stored on electrically movable banks of shelving. As of 1985, Building 1420 became general purpose warehousing, which was the actual intent of its 1952 design by L.P. Kooken.[51] The second Special AMC Warehouse at Kelly was Building 1534, a 720,000 square-foot generic supply warehouse (originally planned for 480,000 square feet).[52] Both warehouses were 400 feet wide, but of differing lengths. The warehouse for the Directorate of Special Weapons (Building 1420), had a square footprint, 400 by 400 feet (Plate 100), while dimensions of the supply warehouse (Building 1534) were 400 by 1,800 feet (Plate 101). The supply warehouse also featured rail access, similar to such warehouses at McClellan and Robins, for example (see Plate 97).

The most comprehensive Cold War mission of the SAAMA was the overhaul, maintenance, repair, and supply for aircraft assigned to the depot by Air Materiel Command. During the 45 years of the conflict, Kelly hosted major missions for the B-26 and B-29 in support of the Korean War and early atomic weapons tests and for the B-36, B-47, B-52, B-58, B-70, C-45, C-131, C-5, F-102, F-106, L-5, L-23, T-29, and T-34. In some cases, the missions were prime maintenance and supply (as for the B-36). In other cases, depot tasks were quite specific. One example of a focused assignment was adaptation of the C-131E to an air evacuation configuration for the Military Air Transport Service in late 1957.[53] The SAAMA also sustained major engine repair programs in support of aircraft maintenance. For the B-36 and XC-99, the depot managed engine testing for the Pratt & Whitney R4360, the workhorse engine for the bomber and its cargo version.[54] For the engine test mission, Air Materiel Command built a complex of facilities during 1951-1954, including a cleaning tank (adjacent to Building 329), engine box repair shop (Building 366B), engine test preparation shop (Building 339), and engine test cells (Building 341). The SAAMA handled the engine test compound as four separate projects. The first one enclosed existing "Jacobson Outdoor [test] Stands" from World War II (in Building 341), while successive construction phases added new test cells.[55] (Plate 102). In the early 1970s, the SAAMA added a $12,500,000 engine overhaul building (Building 360) to its engine test complex. The St. Louis engineering firm of Sverdrup & Parcel designed this structure. The firm had been responsible for the master planning of the Arnold Engineering Development Center during the late 1940s and 1950s at Tullahoma, Tennessee, and had designed an unusual two-aircraft run-up shop for the F-4 at Hill in the middle 1960s (see Volume I, Part II, and, Volume II, Chapters 1 and 6).[56] Other responsibilities at Kelly included modification / IRAN (for example, the B-47) and specialized repair (the B-52 and C-5). In the cases of the B-52 and C-5, the depot mission began as specialized repair and changed over to modification / IRAN. Both the B-52 and C-5 assignments were very long. Air Materiel Command / AFLC assigned the B-52 to Kelly in 1955-1956 and the C-5 in 1965-1971. Work on these aircraft continued at the depot past the end of the Cold War.[57]

The process of maintenance and repair under the modification / IRAN program for the B-52 during 1959 offers a representative illustration of the complex and interrelated tasks comprising aircraft work at the depot. The B-52 mission had arrived as a single aircraft in fiscal year (FY) 1956 to establish prototype standards for the bomber's modification / IRAN at Kelly. During FY 1957, the SAAMA completed modification and IRAN on four B-52s, ratcheting up to 28 B-52s during FY 1958. Air Materiel Command planned for the depot to handle 85 B-52s in FY 1960, with a period of two and one-half months of down time for each bomber. IRAN was to return planes to active use in a "like new condition." In an 11-phase program, the B-52 arrived at Kelly for a SAC crew debriefing, followed by a radioactivity check, de-arming, and defueling. After removal of the engines, drop tanks, and alternators, personnel next stripped all peeled paint and thoroughly washed the aircraft outdoors at an allocated apron area. Men and women purged fuel tanks and blew out all fumes before the B-52 entered the overhaul hangar (Building 375). Inside the hangar, men proceeded with multiple inspections and examinations, next completing specific repairs and modifications on different parts of

Plate 100: L.P. Kooken and Ammann & Whitney. "Special AMC Warehouse" of 1951 constructed as the Special Weapons Warehouse (Building 1420), Kelly Air Force Base, 1954-1957. View of 1954-1955. In *History of San Antonio Air Materiel Area 1 July – 31 December 1954.*

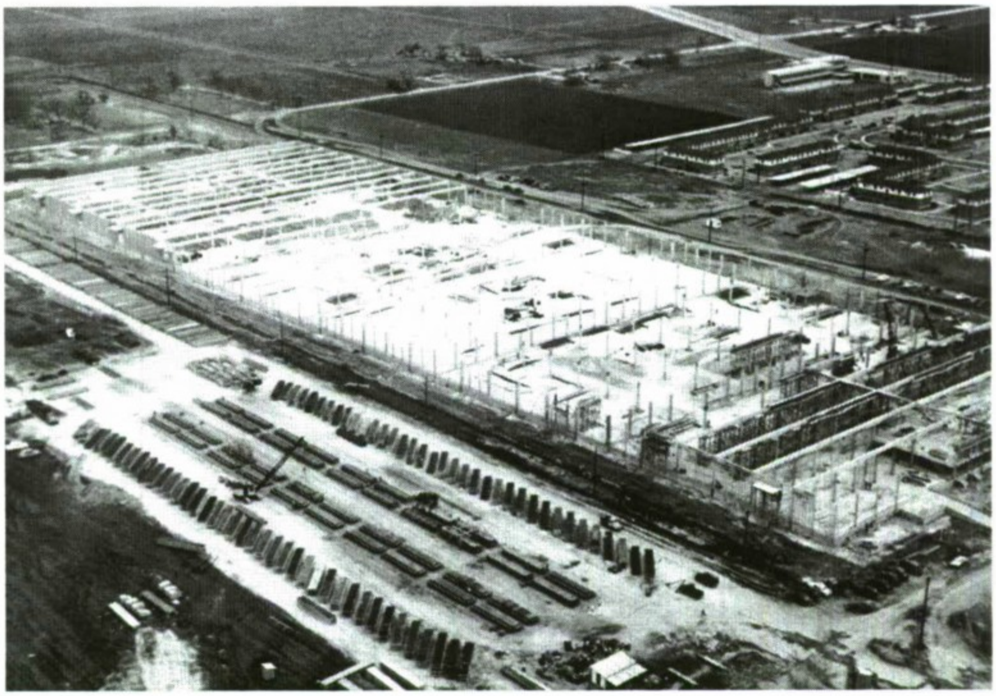

Plate 101: L.P. Kooken and Ammann & Whitney. "Special AMC Warehouse" of 1951 constructed as the Depot Supply Warehouse (Building 1534), Kelly Air Force Base, 1954-1957. View of February 1955. In *History of San Antonio Air Materiel Area 1 July – 31 December 1954.*

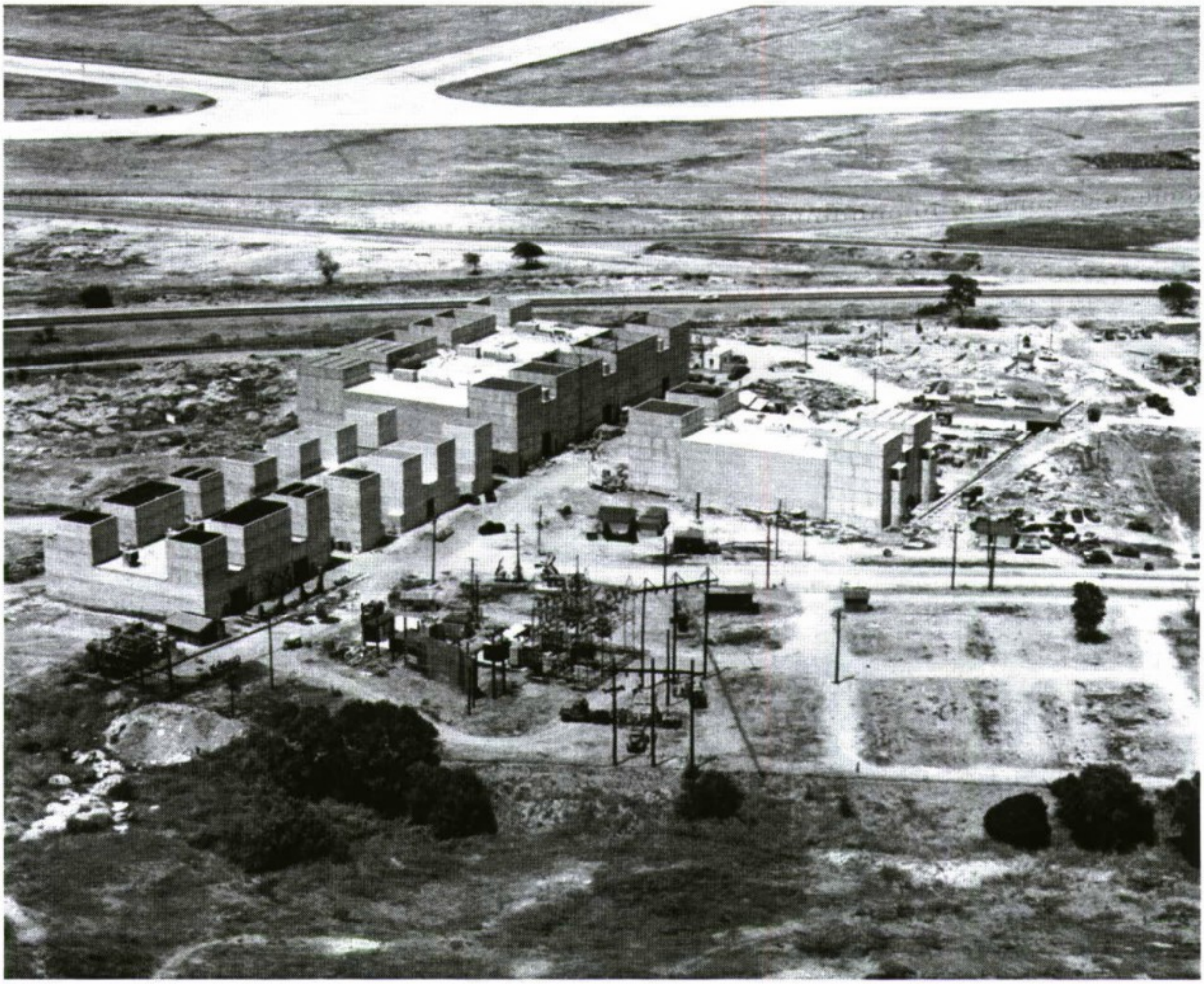

Plate 102: Engine Test Cell Area (Buildings 339, 341, and 366B), Kelly Air Force Base, 1951-1954. View of 1954. In *History of San Antonio Air Materiel Area 1 January – 30 June 1954.*

the aircraft simultaneously. Personnel also removed numbers of individual items on the bomber, like the ejection seats (for stripping, cleaning, and painting) and wing flaps (for inspection of structural damage and rib / skin replacement as needed). Work crews removed the engines for major inspection and overhaul. After personnel had repaired and replaced all systems, the B-52 left the hangar for a final operational inspection and fueling, followed by flight test, touch-up painting, and equipment loading prior to turnover to SAC.[58]

Air Materiel Command assigned the C-5 to Kelly in late 1965, well before the first flight of the plane in June 1968 at the Lockheed plant in Marietta, Georgia, neighboring Dobbins Air Force Base (AFP 6) (see Volume II, Chapter 15). The C-5 arrived at Kelly in April 1971 for its initial maintenance. In preparation for the aircraft, the SAAMA converted an inactive engine test cell for C-5 tests (in the group of cells located with Building 341) (see Plate 102) and installed an airtight, electrically heated autoclave chamber in the overhaul hangar (Building 375) to bond aircraft components at the required elevated temperatures. The C-5 was the cargo aircraft that resulted from XC-99. Even larger than the XC-99, the C-5 was over 230 feet long, with a wingspan of 220 feet, tail height of 63 feet, and weight of 700,000 pounds. The overhaul hangar could accommodate six of the aircraft at one time. A special design feature of the C-5 made it possible for the SAAMA to use Building 375: work crews

were able to lower the rear of the aircraft—which in turn allowed its tail to clear the 60-foot doors.[59] In April 1972, SAAMA personnel also adapted both bays of the Operations - Transport Squadron and Flight Test Hangar (Building 365) by adding a six-story extension. The new façade of the hangar included doors 70 feet high. The modification permitted personnel to maneuver the C-5 into the World War II hangar. In addition, the remodeled Building 365 fully enclosed the plane and its increased vertical dimensions enabled crews to raise the aircraft to its full height of 63 feet (Plate 103). Building 365 became the paint hangar for the C-5.[60] Generally across Air Materiel Command depots, paint hangars for large aircraft post-1965 included both completely new structures (such as at McClellan) and creative adaptations of preexisting buildings (such as at Kelly and Robins) (see Volume II, Chapters 10 and 11).

Kelly sustained a wide variety of other depot and tenant missions throughout the Cold War period that are not discussed in detail here. For example, immediately after World War II the installation participated in maintenance and supply training of foreign officers. One of the first of these missions was for Chinese officers in November 1946.[61] Between 1948 and 1951, Kelly personnel trained many Turkish officers, and in a lesser effort, officers from Saudi Arabia. In yet another effort, the installation participated in the Lend-Lease aircraft program to Central and South America. Manufacturers flew their planes to Kelly, where foreign military pilots picked them up and ferried them home. Kelly was also active in the Foreign Military Sales during the 1970s and 1980s. Men and women at the depot prepared aircraft for sale to Columbia, Indonesia, Jordan, Saudi Arabia, Yemen, Iran, Korea, Pakistan, Singapore, Taiwan, Thailand, and Turkey. Beginning in 1980, in a program specifically for the F-5, Kelly provided technical support assistance to increase aircraft reliability and maintenance quality for 13 countries.[62] From the late 1940s into the middle 1950s, the

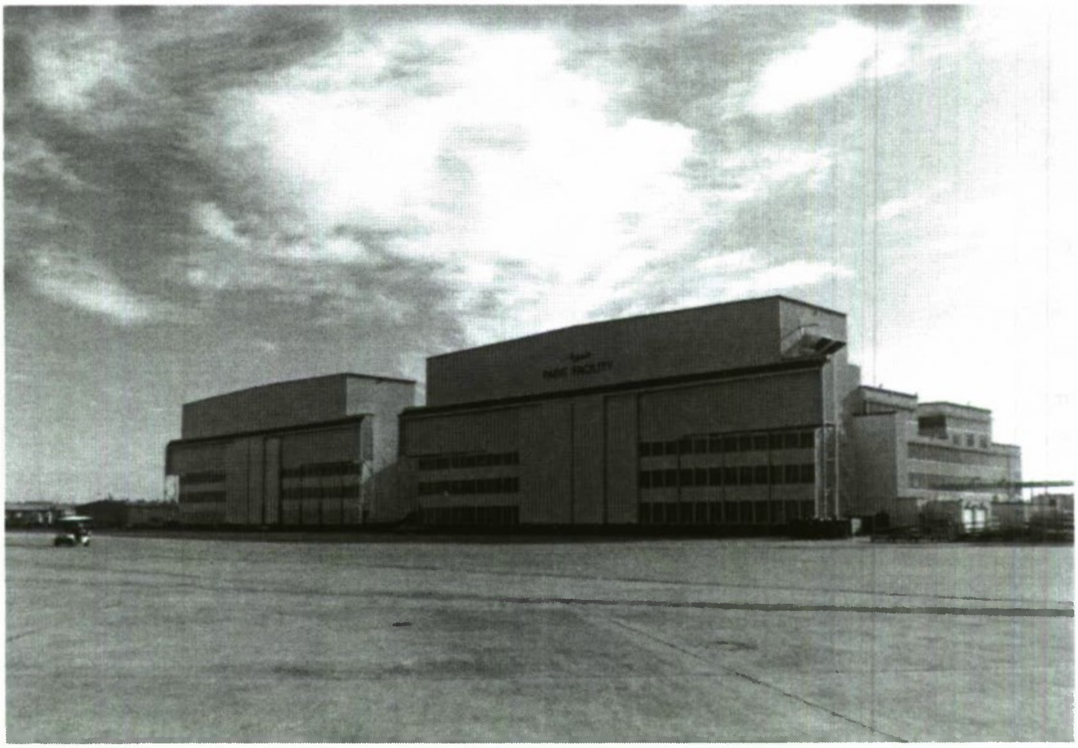

Plate 103: Albert Kahn and Fred N. Severud. Operations - Transport Squadron and Flight Test Hangar (Building 365), Kelly Air Force Base. The SAAMA modified the early 1940s building in 1972 as a paint hangar for the C-5. Photograph of December 1999. D.E. Williams for EDAW, Inc.

SAAMA supported a training squadron for depot group specializations.[63] In 1956, Kelly hosted ANG's 182nd Fighter-Interceptor Squadron. The squadron sustained air defense duties at the base into at least the middle 1970s.[64] And in 1968, logistics management for the Department of Defense working dogs program transferred within San Antonio Air Force installations from Lackland to Kelly. Air Training Command continued to train the animals and their handlers at the new location.[65] For the Vietnam War, the SAAMA (San Antonio Air Logistics Center [ALC] as of 1974) modified aircraft for shipment to the Pacific and managed projects IGLOO WHITE and PAVE EAGLE. The latter two missions were both intelligence gathering efforts, which in turn provided information to USAFSS / Electronic Security Command analysts on Kelly's Security Hill.[66]

Kelly also handled a number of NASA support projects from August 1962 through the end of the Cold War. In the early 1960s, the SAAMA loaned aircraft to NASA for astronaut proficiency training at the Houston Manned Flight Center. In 1964, the Directorate of Maintenance at the depot manufactured three Apollo capsule trainers for NASA. The agency used the trainers to test different challenges of manned spacecraft. The next year, the maintenance shops at Kelly fabricated human and animal gravity couches (G couches) for the Aerospace Medical Center at Brooks. The Aerospace Medical Center needed the G couches to indoctrinate and train men and women selected for NASA's Gemini and Apollo programs, as well as for studies of human response and tolerance to various acceleration forces in centrifuge tests. Kelly provided aerospace fuels to NASA from 1966 forward. In late 1979, the installation worked on NASA's Super Guppy aircraft (made from parts of a Boeing 377 and C-97). The Super Guppy transported space shuttle components for NASA. At Kelly, personnel replaced the aircraft's landing gear.[67]

Key Associated Architects and Engineers

Architectural-engineering firms who designed buildings and structures at Kelly Air Force Base during the Cold War included several of major significance. These firms are discussed in Volume I and in other chapters of Volume II, as noted:

- Ammann & Whitney, of New York (Volume I, Part II);
- L.P. Kooken, of Baltimore (Volume I, Part II);
- Kuljian Corporation, of Philadelphia (Volume II, Chapter 3);
- Fred N. Severud, of New York (Volume II, Chapter 4); and,
- Sverdrup & Parcel, of St. Louis (Volume II, Chapter 1).

Also worthy of comment are the 10 sets of B-36 wing docks and nose shelters contracted by Air Materiel Command at Kelly. Throughout the Cold War period, the Directorate of Maintenance at Kelly designed and fabricated work stands, aircraft engine and nose shelters, and NASA training capsules. The B-36 wing docks may be unique within the Air Force. Air Materiel Command contracted with the East Texas Engineering Company for their manufacture, but it is not known whether that company designed the B-36 docks or whether it merely made them to Air Force specifications. Further research on these docks may offer important additional insights about the Air Force design and engineering process for ephemeral maintenance facilities. The wing docks no longer exist at Kelly, but one or more of the structures may still remain at locations in San Antonio. Air Materiel Command sold several of the docks and gave others to area schools in the late 1950s when the B-36 ended at the depot.[68]

The large aircraft repair hangar (Building 375) of 1952-1956 is the second structure at Kelly that deserves additional research. This building was only erected once for Air Materiel Command (unlike most Air Force structures that are constructed in multiples). Its design is coincident with a research contract of 1952-1954 between Headquarters Air Materiel Command and Austrian architect-engineer

Konrad Wachsmann. Wachsmann was then teaching in the Department of Engineering at the Illinois Institute of Technology. His work on a spaceframe cantilever hangar for the command derived from a patented design of the middle 1940s with another immigrant engineer, Hungarian Paul Weidlinger. The long exploration of engineering for a very large hangar, built as modules and expansible, includes the Wachsmann designs of 1944-1954 for a spaceframe hangar and those of the Kuljian Corporation of 1951-1953 for the double-cantilever hangar and Building 375. (The Air Force erected approximately 55 of the double-cantilever hangars in the continental United States and at selected bases overseas between 1951 and 1956.) A strong likelihood exists that the Wachsman and Kuljian designs are interrelated through an explicit Headquarters Air Materiel Command R&D project for such a hangar during these same years.

---

[1] Charles E. Crain, Jr., and Robert S. Giles (eds.), *A Pictorial History of Kelly Air Force Base* (Kelly Air Force Base: Office of History, San Antonio Air Logistics Center, ca.1981), 1-77. *A Pictorial History of Kelly Air Force Base* presents a solid overview of the historic installation and its missions over time. In minor instances, the text is confusing or contradictory, but presented information can easily be cross-checked within the volume. A number of other briefer historic studies complement the Crain and Giles effort, including: Juan Montoya and Ann Krueger Hussey, *A Brief History of Historical Sites and Structures on Kelly Air Force Base* (Kelly Air Force Base: Office of History, San Antonio Air Logistics Center, April 1993); Kathi R. Jones, *A Brief History of Kelly Air Force Base*, SA-ALC Pamphlet 84-1 (Kelly Air Force Base: Office of History, San Antonio Air Logistics Center, versions of October 1995 and June 1999); Ann K. Hussey, *The History of Aircraft Maintenance at Kelly Air Force Base* (Kelly Air Force Base: Office of History, San Antonio Air Logistics Center, ca.1998); and, Ed Alcott, Robert Browning, Dick Emmons, Ann Hussey, Thomas Manning, Pat Parrish, and Edgar Sneed, *A History of Military Aviation in San Antonio* (San Antonio: United States Air Force, September 1996). The reader can also refer to the chapter on Kelly Air Force Base in Robert Mueller, *Active Air Force Bases within the United States of American on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). The chapter provides a good resource for tracking lineage questions at the base, including the sequence of installation names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of assigned units assigned.

[2] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 73-74.

[3] Today's Building 365 was originally numbered as two structures, Buildings 361 and 365, in recognition of its two hangar bays.

[4] Montoya and Hussey, *A Brief History of Historical Sites and Structures on Kelly Air Force Base*, 1993, 25-26.

[5] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 121-123.

[6] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., January 2001), 154-156.

[7] Air Materiel command, *History of San Antonio Air Materiel Area 1 July – 31 December 1948*, Classified [originally] Annex to Installment VI, 1-3.

[8] Air Materiel Command, *History of San Antonio Air Materiel Area 1 July – 31 December 1953*, 307.

[9] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 179.

[10] Air Materiel Command, *History of San Antonio Air Materiel Area 1 January – 30 June 1955*, 23.

[11] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 287.

[12] *Ibid*, 281, 293-295, and 300-305.

[13] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 97-104.

[14] Robert Mueller, *Active Air Force Bases*, 1989, 273.

[15] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 95, 115.

[16] *Ibid*, 146-147.

[17] *Ibid*, 119, 178.

[18] *Ibid*, 146-147.

[19] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 63-84.

[20] The terms "nose dock," "wing dock," and "wing hangar" are sometimes found interchangeably during this period, although mechanics working with the structures most commonly use(d) the term nose dock for the entire

category of structure. A nose dock always covered the "nose" of the aircraft and usually the whole of the plane from the wings forward, while a wing dock often sheltered only the wings. A small, makeshift nose shelter often accompanied wing docks, is the case for the B-36 docks at Kelly.
[21] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 147; and, Air Materiel Command, *History of San Antonio Air Materiel Area 1 January – 30 June 1953*, 116B.
[22] Air Materiel Command, *History of San Antonio Air Materiel Area 1 January – 30 June 1953*, 85.
[23] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 147. Crain and Giles describe the original B-36 work area as near "Building 359." This structure no longer exists today, but was located immediately to the northeast of Building 365. Building 359 is documented on a numbered base map of 1945: United States Engineer Office, San Antonio District, "Kelly Field, Texas, Base Layout Plan," 10 April 1945. The structure is also still present on the master plan for Kelly of 1957. See Plate 97.
[24] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, photographs on 149 and 154. These photographs are taken inside Building 365, and document work on both the B-36 and XC-99. The bomber and cargo aircraft could pull into the hangar to a point just past the rear edges of their wings.
[25] *History of San Antonio Air Materiel Area 1 January – 30 June 1953*, 85.
[26] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 148.
[27] *Ibid*, 147-149.
[28] *Ibid*, 149.
[29] The height of the XC-99's tail fin is noteworthy in terms of the aircraft's maneuverability for maintenance and overhaul. While the Airplane Repair Building of the late 1930s (erected at Kelly as Building 1610) could accommodate the tail of the B-36—which had a height of not quite 50 feet—it did not allow the tail of the XC-99 to enter the hangar. The maximum entry for an aircraft tail was 52 feet. In this regard, the Operations - Transport Squadron and Flight Test Hangar (Building 365 at Kelly) was a much improved hangar and was evocative of Fred Severud's talents as an engineer. Maintenance crews could never maneuver the rear of the XC-99 into an Airplane Repair Building, while they could pull the XC-99 or B-36 backwards into the Operations - Transport Squadron and Flight Test Hangar if major overhaul on the rear sections of the aircraft required a covered workspace.
[30] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 150-159.
[31] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 35-58.
[32] "Rigid-Frame Truss Supports the World's Biggest Hangar," *Engineering News-Record* 156, 5 (2 February 1956): 24; Kuljian Corporation, "Aircraft Repair Hangar Longitudinal and Cross Sections," drawing J-104-34-A, 3 March 1953.
[33] American Bridge, "Whopping Big Any Way You Look at It," *Engineering News-Record* 155, 17 (27 October 1955): 39.
[34] "Building 375," vertical file of clippings and typescripts for planning, construction, and use, History Office, Kelly Air Force Base. Location of the files pending full base realignment in July 2001 is anticipated as Lackland. See also, Air Materiel Command: *History of San Antonio Air Materiel Area 1 July – 31 December 1953*, 308-309; *History of San Antonio Air Materiel Area 1 January – 30 June 1954*, 315-316.
[35] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 231-232.
[36] Basic information is derived from Dennis F. Casey and Gabriel G. Marshall, *A Continuing Legacy: USAFSS to AIA 1948-1997* (Kelly Air Force Base: History Office, Air Intelligence Agency, 1997); see also, Heather Puckett and Andrea Urbas, *Cold War Historic Building Inventory and Evaluation Security Hill, Kelly Air Force Base* (Colton, California: Earth Tech for the Air Intelligence Agency, May 1998).
[37] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 159-160.
[38] *General Outline Specifications for Standard Air Force Buildings*, 1952; and, "Planning Buildings for the U.S. Air Force," *Architectural Record* 111, 1 (January 1951): 96-126.
[39] Tracing Air Force architectural-engineering design is complicated. Typically, the Air Force hired a firm to develop a design for a "type" of building. Sometimes, the needed structure was unusual and had detailed specifications. In these instances, a civil engineering office ("air installations") at Wright-Patterson under Air Materiel Command provided guidance to a firm as it worked through the early design process. Once the Air Force had accepted a design, however, its originating architectural-engineering firm very quickly became obscured. When a base chose to erect a particular building (for example, the Kuljian double-cantilever hangar of 1951), the regional Army Corps of Engineers district would forward a set of the "standard" drawings—including any updates or revisions—to the installation, who in turn would send these to the architectural-engineering firm hired for the job at the local level. In most cases, the local firm spliced its own name into the

title blocks of the drawings, but left the formal Air Force "title" of the building and its originating Air Force-wide drawing series number. The numbering, in particular, is an excellent method of beginning to track down the actual architects and engineers for the buildings, although this process is difficult and often requires a search process in archives in Washington, D.C. The Air Force also hired later architectural-engineering firms to make master drawings sets called "definitives." These firms took the work of other firms for individual buildings and added any minor modifications that were a part of project files (a change to an overhead door track mechanism for example). Like the local firms hired to manage actual construction and site adaptation, the firms hired at a national level to print a "clean" set of drawings across building types also spliced in their firms' names into title blocks. This situation really confuses the accuracy of research. The firms responsible for the master sets changed every few years, but the buildings often did not for a decade or more. The firms making the master drawings also almost always had nothing to do with the original design or its adaptation anywhere. One can find drawings for an identical building—again, like the double-cantilever hangar—with multiple architectural-engineering firms appearing to be the "designers" and with multiple "dates." In reality, only Kuljian Corporation designed the double-cantilever hangar—finalized in late 1951 and built thereafter with only very minor upgradings and site-specific changes (like those pertinent to foundations). Making this even more convoluted, an aborted design for a first attempt at a double-cantilever hangar by Mills & Petticord exists for early 1951—different from Kuljian's final design. The Air Force erected the Mills & Petticord hangar (also known as the Pacific Iron and Steel hangar) twice while it worked out issues toward the standard design. See Volume I, Parts II and III, and Volume II, Chapter 8.

[40] Frank Grad & Sons, "Mess & Admin. Bldg.-Airmen 500 Men One Story Masonry +20 Degree Zone Elevations," drawing 36-05-63, 28 September 1951. See also, Frank Grad & Sons, drawing for Building 1250, Edwards Air Force Base, 1951 (discussed in Volume II, Chapter 3).

[41] Karen J. Weitze, Carrie Gregory, Lori Lilburn, and Angie Gustafson, *Eglin Air Force Base Inventory of Historic Properties 2001-2003, Part I*, Draft (San Diego: EDAW, Inc., for Air Force Materiel Command, February 2002), "Buildings 17 and 20."

[42] Barlett Cooke and W.E. Simpson Company, "Airmen's Barracks Connecting Utilities Kelly Air Force Base," May 1951, and, Puckett and Urbas, *Cold War Historic Building Inventory and Evaluation Security Hill, Kelly Air Force Base*, 1998, 4-2.

[43] Air Materiel Command: *History of San Antonio Air Materiel Area 1 January – 30 June 1952*, 6; *History of San Antonio Air Materiel Area 1 July – 31 December 1952*, 6-7; *History of San Antonio Air Materiel Area 1 January – 30 June 1953*, 303B and photograph; *History of San Antonio Air Materiel Area 1 July – 31 December 1953*, 4, text and photograph after 312.

[44] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 98.

[45] Air Materiel Command, *History of San Antonio Air Materiel Area 1 July – 31 December 1955*, 17-20.

[46] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 98. Also, see Volume I, Part I.

[47] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 285-286; Karen J. Weitze, *PAVE PAWS Beale Air Force Base: Historic Evaluation and Context* (Sacramento: KEA Environmental, Inc., for Air Combat Command, February 1999), 31.

[48] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 286-287.

[49] Montoya and Hussey, *A Brief History of Historical Sites and Structures on Kelly Air Force Base*, 1993, land use map on inside cover.

[50] Air Materiel Command: *History of San Antonio Air Materiel Area 1 July – 31 December 1955*, 185; *History of San Antonio Air Materiel Area 1 January – 30 June 1957*, 199-201.

[51] San Antonio Air Logistics Center: "Talking Paper," 10 January 1983; "Near Term Initiative," 12 January 1983; and, "Master Storage and Warehousing Plan," 1 December 1985. Vertical file for Building 1420, History Office, Kelly Air Force Base. Location of the files pending full base realignment in July 2001 is anticipated as Lackland.

[52] Air Materiel Command: *History of San Antonio Air Materiel Area 1 July – 31 December 1953*, 312; *History of San Antonio Air Materiel Area 1 July – 31 December 1954*, 392.

[53] Air Materiel Command, *History of the San Antonio Air Materiel Area 1 July – 31 December 1957*, plate and text.

[54] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 160, 176.

[55] *History of San Antonio Air Materiel Area 1 January – 30 June 1953*, 6, 301-302; *History of San Antonio Air Materiel Area 1 July – 31 December 1953*, 309-310; *History of San Antonio Air Materiel Area 1 January – 30 June 1954*, 316A, 317, and photograph; *History of San Antonio Air Materiel Area 1 July – 31 December*

1954, 15. The World War II test stands are described as "Jacobson" stands in *History of San Antonio Air Materiel Area 1 July – 31 December 1953*, 309, but are transcribed as "Johnson Outdoor Stands" in Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 160. The latter citation is probably the one in error.
[56] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 450-451.
[57] *Ibid*, *passim*; Hussey, *The History of Aircraft Maintenance at Kelly Air Force Base*, ca.1998.
[58] San Antonio Air Materiel Area, "B-52 Program," ca.1959. Vertical file for B-52, folder 2, History Office, Kelly Air Force Base. Location of the files pending full base realignment in July 2001 is anticipated as Lackland.
[59] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 371-394.
[60] *Ibid*, 386, 407.
[61] Air Materiel Command, *History of San Antonio Air Materiel Area 1 July – 31 December 1946*, 135, 153.
[62] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 132-138, 394-396, 448-449.
[63] *Ibid*, 139.
[64] *Ibid*, 222; *History of San Antonio Air Materiel Area 1 January – 30 June 1957*, 201-202.
[65] Crain and Giles, *A Pictorial History of Kelly Air Force Base*, ca.1981, 315-323.
[66] *Ibid*, 267-278.
[67] *Ibid*, 280-282.
[68] *Ibid*, 149.

Chapter 8: Kirtland Air Force Base

Historic Missions of the Cold War

The primary Air Force missions at Kirtland Air Force Base during the 45 years of the Cold War have focused on the development of nuclear weapons systems and studies of nuclear weapons effects. The Army established Albuquerque Army Air Base in March 1941.[1] The installation was soon known as Kirtland Field. Two Santa Fe Railroad employees had inaugurated a private venture for an airport on the site of the later military base in 1928, with a competing second civilian airfield nearby as of 1929. By the end of the 1930s, one of the airfields evolved into the Albuquerque Municipal Airport, while the other continued as a private enterprise, Oxnard Field. With war in Europe as of late 1939, Albuquerque civic leaders proposed locating an Army airfield adjacent to the town's airport. During World War II, the Army base initially served as an enroute service point for aircraft ferried to England. While most of the buildings erected at the installation were temporary, the Army Air Corps did choose—from the beginning—to build a 10,000-foot runway suitable for heavy bombers. Kirtland Field next became the location of a training school for the Army focused on pilot flight time in B (bomber) -17s and B-24s. The Army next added a bombardier school on surrounding vacant lands for practice drops. The bombardier school remained the installation's major World War II mission, supplemented by other training programs for mechanics and pilots. At the end of the war, Kirtland Field sustained a B-29 mission, and transitioned into its Cold War role through its support of the Los Alamos Laboratory during 1944 and 1945. The laboratory was located several hours north of Kirtland Field in Los Alamos, New Mexico, and was an important part of the Manhattan Project to develop an atomic bomb.

When the United States decided to continue testing the atomic bomb in the Marshall Islands of the Pacific in 1946, the Army Air Forces selected Kirtland Field as the logical installation for nuclear weapons development. The base's proximity to the Los Alamos Laboratory that had designed and engineered the bomb was a key factor, as was the relocation of the Z Division of the laboratory to Oxnard Field (neighboring Kirtland) in late 1945. Named for Jerrold R. Zacharias, an important member of the Manhattan Project team at Los Alamos, Z Division evolved into Sandia Base (later, Sandia Corporation / Sandia National Laboratories) and had responsibility for receiving, storing, assembling, testing, and improving atomic bombs. The runway and bomb loading pit at Kirtland Field, used to fit the first bombs to B-29s bound for Wendover Army Air Field in Utah (see Volume II, Chapter 6) and thence to the Pacific war theater, were the major factors shifting this component of the Los Alamos Laboratory to a site adjacent to the installation. During the late 1940s, Kirtland Field (Kirtland Air Force Base as of 1948) directly supported atomic testing in the Marshall Islands and at the Nevada Proving Ground (later, the Nevada Test Site). In 1949-1950, the base also featured one of the first Air Defense Control Centers (ADCCs) for Air Defense Command (ADC) and had affiliated responsibilities for subordinate Aircraft Control & Warning (AC&W) radar stations located in the air defense sector. (For a brief period at the outset of the 1960s, the ADCC at Kirtland would also function as a manual Semi-Automatic Ground Environment [SAGE] Direction Center.) By 1952, the air defense mission at Kirtland centered on the need to protect the Los Alamos Laboratory to the north and Sandia Base next door. The mission was a very important one and included an ADC fighter-interceptor squadron (FIS) on alert. By mid-decade, Strategic Air Command (SAC) aircrews trained on base in Air Training Command (ATC) courses focused on nuclear weapons handling for the B-36.

From the late 1940s through the end of the Cold War, missions associated with nuclear weapons became more and more complex at Kirtland, including atomic and thermonuclear bombs, and nuclear warheads for the range of missiles in development and test. Early in the 1950s, the base also functioned as the Air Research and Development Command (ARDC) hierarchical point of

responsibility for the overall special weapons program. "Special weapons" was an umbrella grouping for atomic, biological, and chemical weapons systems. The program emphasized research and development (R&D) of warheads for guided missiles, as well as other delivery schemes. Beginning in 1956, ARDC assigned Kirtland the task of sophisticated civil engineering studies for the command (and often for the Air Force overall), centered on issues of nuclear hardening. By the early 1960s, attention turned to analyses and tests addressing nuclear weapons effects, with a major emphasis on simulation techniques. During the later Cold War, personnel at Kirtland worked on laser, particle beam, and other advanced weapons systems.

The sequence of host commands at Kirtland throughout the Cold War period is less straightforward than at most bases within Air Force Materiel Command. Toward the end of World War II, SAC (through the Second Air Force) took over as host command for Albuquerque Army Air Base from the Army Air Forces Training Command. The Army Air Forces inactivated the installation before the close of 1945. For a brief period of months during 1946, ADC maintained the base through the Fourth Air Force, followed again by SAC (through the Fifteenth Air Force and subsequently the Eighth Air Force) until December. At the beginning of that month, Air Materiel Command hosted the installation. The 1947-1949 years were focused on the construction of atomic bomb storage facilities at Manzano Base, a facility built into the Manzano Mountains. Air Materiel Command took over the specialized depot mission after Manzano Base was operational. (During the late 1940s, Kirtland was a subinstallation for the San Antonio Air Materiel Area (SAAMA) located at Kelly Air Force Base in Texas [see Volume II, Chapter 7].) The chain of command was especially complex. In January 1947, the Armed Forces Special Weapons Project (AFSWP), a liaison organization between the Atomic Energy Commission (AEC) and the War Department with selected members from the Army, Army Air Forces, and Navy, delegated construction, training, and initial management to Sandia Base, with Sandia facilities located immediately adjacent to Kirtland. The AFSWP was headquartered in Washington, D.C., with a field unit at Sandia. (In mid-1959, the Defense Atomic Support Agency [DASA] replaced the AFSWP, followed by name changes to the Defense Nuclear Agency [DNA], the Defense Atomic Support Information Activity Center [DASIAC], and the Defense Threat Reduction Agency [DTRA] / Defense Threat Reduction Information Analysis Center [DTRIAC].) The Z Division of Los Alamos, the original core unit for Sandia Base, worked directly with AFSWP personnel. In turn, the AFSWP began training personnel in Air Materiel Command to carry out the functions of those special munitions depots under Air Force jurisdiction (among the National Storage Sites [NSSs] and Operational Storage Sites [OSSs] of the overall program). By the middle 1950s, the Aviation Depot Squadrons of Air Materiel Command managed nuclear bomb storage areas across the United States, including OSSs at five SAC bases.[2] For a brief period from December 1949 to April 1952, the Air Force Special Weapons Command oversaw Kirtland, following on the heels of Air Materiel Command.

As of April 1952, ARDC became host command at the installation, a situation that continued when ARDC's name changed to Air Force Systems Command (AFSC) in 1961. Once formally under ARDC, Kirtland also supported the Air Force Special Weapons Center, one of the distinct research, development, testing, and evaluation centers within the command. The laboratories of the Research Division of the Special Weapons Center were an Air Force counterpart to the laboratories run by the University of California at Los Alamos (the Los Alamos National Laboratories) and at Livermore, California (the Lawrence Livermore National Laboratories), as well as to those of Sandia, and were strongly focused on nuclear weapons research and analysis. (Both the Los Alamos and Livermore Laboratories became AEC facilities in the early 1950s, and are Department of Energy [DOE] facilities in 2003, operated by the University of California.) Representatives of both Sandia and the AEC (later, DOE) maintained personnel at Kirtland. After the title shift from ARDC to AFSC in 1961 and the cessation of aboveground nuclear testing through the Limited Nuclear Test Ban Treaty two years later (see Volume I, Part I), the Research Division of the Special Weapons Center

metamorphosized into the Air Force Weapons Laboratory (AFWL) and was subsumed beneath the Special Weapons Center (see Volume I, Part II). The AFWL advised the Air Force Special Weapons Center on nuclear matters, in addition to other specialized research assignments. In 1970, the Air Force Missile Development Center at Holloman Air Force Base in southern New Mexico merged with the Special Weapons Center at Kirtland and shifted the emphasis at the Special Weapons Center to missiles development. The next year, Kirtland acquired the adjacent lands of Sandia Base, which increased the installation's size from 2,800 to 54,000 acres. Both the Sandia National Laboratories and the DOE maintain major facilities on Kirtland in 2003.

A final series of command changes at Kirtland began during 1976-1977. In March 1976, AFSC abolished the Air Force Special Weapons Center, and the Air Force Contract Management Division of AFSC became the base host. The Air Force Contract Management Division was one of six divisions within a reorganized AFSC structure in 1974 (see Volume I, Part II). In 1977, Military Airlift Command (MAC) replaced AFSC as host. At that time, AFSC's Air Force Contract Management Division became a tenant at Kirtland, while the command's AFWL was subsumed under the Space and Missile Systems Organization (SAMSO) at Los Angeles Air Force Station. SAMSO was also a tenant at Kirtland (see Volume I, Part II). In October 1982, the AFWL became one of six laboratories managed through a Director of Laboratories at Headquarters AFSC. The command continued to operate the AFWL under Space Division at Los Angeles (one of the follow-ons to SAMSO) as a part of the Air Force Space Technology Center. AFSC located the Air Force Space Technology Center at Kirtland, combining the AFWL, the Geophysics Laboratory at Hanscom Air Force Base near Boston, and the Rocket Propulsion Laboratory at Edwards Air Force Base in California. The Air Force maintained MAC as base host at Kirtland. In 1990, the AFSC laboratory organization simplified further when the six early 1980s laboratories merged into four super laboratories. AFSC renamed the Air Force Space Technology Center, the Phillips Laboratory—with sustained facilities at Kirtland, Hanscom, and Edwards. The Phillips Laboratory included the former Air Force Space Technology Center at Kirtland and its associated laboratories at Hanscom and Edwards. Simultaneous with the creation of the Phillips Laboratory, the AFWL deactivated. As was the case for the Air Force Space Technology Center, the Phillips Laboratory reported to the Space Systems Division at Los Angeles. Only in January 1993 did the Air Force transfer the installation host role at Kirtland from Air Mobility Command, the follow-on to MAC, back to the descendent of ARDC / AFSC—Air Force Materiel Command. The Air Force reconfigured the Phillips Laboratory as part of the Air Force Research Laboratory (AFRL) in 1997.

Primary Missions

The primary Cold War missions of ARDC / AFSC at Kirtland Air Force Base included:

- storage of atomic and thermonuclear bomb components at Manzano Base;
- support of atomic bomb testing in the Pacific and at the Nevada Proving Ground (Test Site);
- support of the Los Alamos Laboratory;
- ballistics, handling equipment, aircraft modification, and developmental tests for existing and proposed atomic and thermonuclear bombs;
- aircraft-weapons fittings, focused on nuclear weapons;
- control over Indian Springs Air Force Base in Nevada for atomic weapons testing;
- coordination for special weapons research, development, testing, and evaluation for ARDC during the early 1950s, including atomic, biological, and chemical weapons systems;
- atomic warhead installations in guided missiles and development of warhead support equipment;
- support of missile testing at the Nevada Test Site and on the White Sands Missile Range in New Mexico;

- guided missile developmental work in coordination with the Air Force Missile Development Center at Holloman;
- contributions toward the improvement of multiple nuclear weapons systems including intercontinental ballistic missiles (ICBMs), antiballistic missiles, and selected cruise missiles;
- nuclear weapons R&D, including simulation techniques for testing nuclear weapons effects;
- specialized civil engineering efforts for the Air Force;
- studies and testing toward nuclear hardening;
- development of technologies to support American military forces in the Vietnam War;
- high-energy laser studies;
- multiple studies for the nuclear surety of Air Force weapons systems, including communications satellites;
- research on particle beams and other advanced weapons concepts;
- participation in space technology research through the Air Force Space Technology Center / Phillips Laboratory; and,
- studies for the Strategic Defense Initiative (SDI) (Star Wars).

Tenant Organization Missions

The host command at Kirtland changed several times during the Cold War. From 1977 through 1992, MAC / Air Mobility Command served as the host on base, with AFSC the main tenant. Major missions at Kirtland for commands other than Air Materiel Command and ARDC / AFSC, including a center reporting directly to Headquarters Air Force, included:

- ADC responsibility for the Albuquerque Air Defense Area (Provisional), followed by activation of the 34th Air Division (Defense) and its ADCC (command post);
- ADC responsibility for multiple AC&W radar stations with the Albuquerque Air Defense Sector;
- a manual SAGE Direction Center for the Albuquerque Air Defense Sector;
- ADC FIS alert, beginning with the 81st Fighter Wing in 1949 and evolving through the 93rd FIS;
- ATC courses to train SAC airmen crews for thermonuclear bomb delivery, including bomb assembly, aircraft bomb loading, and flight test of bomb-loaded aircraft; and,
- the Air Force Test and Evaluation Center in 1973 for armed services-wide test and evaluation missions (later, Air Force Operational Test and Evaluation Center), organized to direct and oversee operational testing of weapons systems. This late Cold War tenant mission directly reflected an earlier one at Kirtland, under Air Proving Ground Command. During 1953-1958, Kirtland supported a detachment from Eglin Air Force Base in Florida for the Air Force Operational Test Center (AFOTC) (see Volume II, Chapter 4).

Adding complexity to the Cold War missions associated with Kirtland Air Force Base was the neighboring, and later on-base, presence of the Sandia National Laboratories and the DOE. While not Air Force tenant missions, these nuclear weapons laboratories were intimately connected to missions of the AFWL and were, like the National Aeronautics and Space Administration (NASA) at Edwards, vital to major activities of the installation.

Chronology

Kirtland's beginnings as three private airfields of 1928-1939 is similar to that of other installations choosing to adapt existing runways and hangars for military use. Frank G. Speakman and William L. Franklin, working with the town of Albuquerque, graded two runways on East Mesa during 1928,

with one approximately 5,300 feet long and the other just under 4,000 feet. Albuquerque Airport was wholly a private enterprise, irrespective of the town's involvement. Immediately following construction for the airport, other individuals and promoters became interested in Albuquerque as a crossroads location for air traffic in the Southwest. James G. Oxnard, a New York entrepreneur, bought half interest in the Albuquerque Airport and expanded the facility before 1928 closed. Original airfield buildings included a small hangar and a multipurpose building functioning as offices and a passenger waiting area, complete with a few hotel rooms for enroute travelers. During 1929, airport owners lengthened the shorter of the two runways, also compacting runway surfaces and applying road oil to control dust. A club house, the Airport Inn, augmented the Albuquerque Airport and offered dining and dancing. Owners also added a second, larger hangar. The airport was a hub for scenic tours, private charter flights, delivery services, regional aircraft record setting, and flight training. As the decade closed, two airlines initiated competitive passenger, mail, and cargo service between the Midwest and California, positioning Albuquerque as an important transcontinental airfield. Shortly after beginning activities, one of the companies, Western Air Express, decided to build its own airport, with hangar and support structures, on West Mesa. Financial difficulties of the early 1930s led to the merger of the two companies, as Transcontinental and Western Air, Inc. (TWA). The new company split a national mail route and developed passenger service coast to coast through Albuquerque. TWA elected to focus its services at the West Mesa airfield, which then became known as the Albuquerque Airport—while the former Albuquerque Airport on East Mesa took on the name Oxnard Field and continued as a private airfield. By the middle 1930s, a second airline, Varney Speed Lines, joined TWA in Albuquerque. During 1937-1939, the growing airline business of TWA and Varney (which had become Continental Airlines) emphasized the need for a new, larger municipal airport for Albuquerque. With the construction of the third airfield in Albuquerque as Europe entered World War II, three facilities existed: the original Albuquerque Airport, sequentially named Oxnard Field and located on East Mesa; the second Albuquerque Airport, renamed the Cutter-Carr Airport in 1939 and sited on West Mesa; and, the third Albuquerque Airport, on East Mesa four miles west of Oxnard Field.[3]

As the third and final Albuquerque Airport opened in 1939 on East Mesa, civic leaders lobbied for the location of an Army military airfield for the community. By late that year, the Army Air Corps leased 2,000 acres neighboring the (third) Albuquerque Airport and construction began on Albuquerque Army Air Base in January 1941 (known alternately as Kirtland Field after February 1942). Among the construction projects was the lengthening of the north-south runway of the late 1930s Albuquerque Airport to 10,000 feet in anticipation of the B-17. Two bombing ranges were attached to the installation, one for light bombing over a six- by 10-mile area northwest of Albuquerque and a second for heavy bombing west of Socorro. Also in late 1939, Army and Navy pilots began using Oxnard Field for refueling and maintenance for a variety of military flights. The Army condemned Oxnard Field for military acquisition, and subsequently formally transferred the land to the federal government. By late spring 1942, Albuquerque Army Air Base was operational at Kirtland Field. The Army Air Forces used the installation for training aircrews for reconnaissance and bombing duty with the B-17, before deployment to the Philippines. The siting of the base adjacent to the Albuquerque Airport, which still functions today as the immediate neighbor to Kirtland Air Force Base, was unusual in the sustained sharing of the primary runway for both military and civilian flights.

During World War II, the blurring of military and civilian distinctions was further shaded when the Army Air Forces hired TWA to train pilots to ferry B-24s from Kirtland to British Royal Air Force (RAF) bases in England. Kirtland Field's 10,000-foot runway supported the training mission. The B-24 program, first known as the Air Corps Ferry Command Four-Engine Transition School, operated for eight months through TWA and became a direct Army Air Forces program in February 1942 (as the Combat Crew Training School). The Army Air Forces moved the training program from

Albuquerque to Tennessee before the close of that year. A second Army school also operated at Albuquerque Army Air Base as of late 1941, a bombardier school moved from Barksdale Field in Louisiana. Personnel constructed targets for the bombing ranges west and southwest of Albuquerque beginning in early 1942. The bombardier school was Albuquerque Army Air Base's primary mission during World War II. The Army Air Forces trained over 5,700 bombardiers at the school by 1945. Of note, the runway at Kirtland Field also allowed the landing of the B-29. As of February 1945, training for the B-29—the Army Air Forces' first very heavy bomber (VHB)—began at the base. Simultaneously, the Los Alamos Laboratory used the runway and bomb loading pit at Kirtland to support development of the atomic bomb during 1944-1945. Three other training programs at Kirtland Field during the war included an aviation mechanics school, a ground school for glider pilots, and a B-24 pilot transition school. This school trained 1,750 B-24 pilots and crew members. The Army Air Forces established the mechanics school at the former Oxnard Field. The installation was physically distinct from the infrastructure at Kirtland Field and known as the Albuquerque Air Depot Training Station. Informally, Army personnel knew the mechanics school—an Air Service Command depot installation—as Sandia Base.[4]

As the Cold War unfolded following the end of World War II, two Army Air Forces installations existed in Albuquerque: an Army Air Forces Training Command base (Albuquerque Army Air Base / Kirtland Field) and, four miles distant, an Air Technical Service Command depot base (Sandia Base / Oxnard Field). Both installations transitioned to the Cold War period through specific activities of late 1944 into September 1945. Los Alamos had first used the runway and bombloading pit at Kirtland Field to fly weapon components and hardware to Wendover Army Air Base, where B-29 crews conducted final testing for delivery of the first atomic bombs. Additional specialized tests, including drop tests using bomb mockups, occurred at Inyokern and over the Salton Sink, both Navy facilities in Southern California that had attached bombing ranges.[5] By late July 1945, Los Alamos desired an assembly and munitions storage area near Kirtland's runway to complete substantial bomb assembly in New Mexico before air transport to Utah. To accommodate progress toward the bomb, the Army Air Forces transferred Sandia Base to the Army Service Forces, Chief of Engineers, and thence to the Manhattan Engineer District—the responsible engineering construction agency for the Manhattan Project through which Los Alamos was developing the atomic bomb. Los Alamos next set up a new internal unit, the Z Division, named for its director Dr. Jerrold Zacharias. Dr. Robert Oppenheimer brought in Dr. Zacharias from his previous assignment with the radar group at the Massachusetts Institute of Technology's (MIT's) Radiation Laboratory (a facility critical to the Manhattan Project that closed in 1945).

The Z Division established itself at Sandia Base as World War II concluded, and work toward improved atomic (and subsequently thermonuclear) bombs became more concentrated at the new Cold War installation. Z Division personnel, as well as assembly specialists from Wendover Army Air Base and Los Alamos ordnance procurement specialists, moved to Sandia Base. The Army Air Forces had been employing Oxnard Field for storage, salvage, and sales of excess aircraft in 1945, thus necessitating the segregation of the classified Z Division activities in a fenced technical area while the Army completed its operations on site. During 1946, Z Division participated in the first post-World War II atomic test in the Marshall Islands, Operation Crossroads (see Volume II, Chapters 4, 10 and 13). At Sandia Base, Los Alamos temporarily housed its personnel in prefabricated structures moved from other Manhattan Engineer District projects. Z Division completed the first phases of construction for what would later be known as Tech Area I during 1947. The division also added an explosives-handling area (Tech Area II).[6] Initial atomic bomb component stockpiling was piecemeal, with remnants sent to Sandia Base from Los Alamos, Kirtland, test sites, and the Marshall Islands in the Pacific.[7] The first special storage site was the 6000 Igloo Area (Buildings 26001-26016), a segregated group of 10 igloos and six small detonator buildings constructed in late 1946 on Sandia Base south of the east end of the east-west runway[8] (Plate 104).

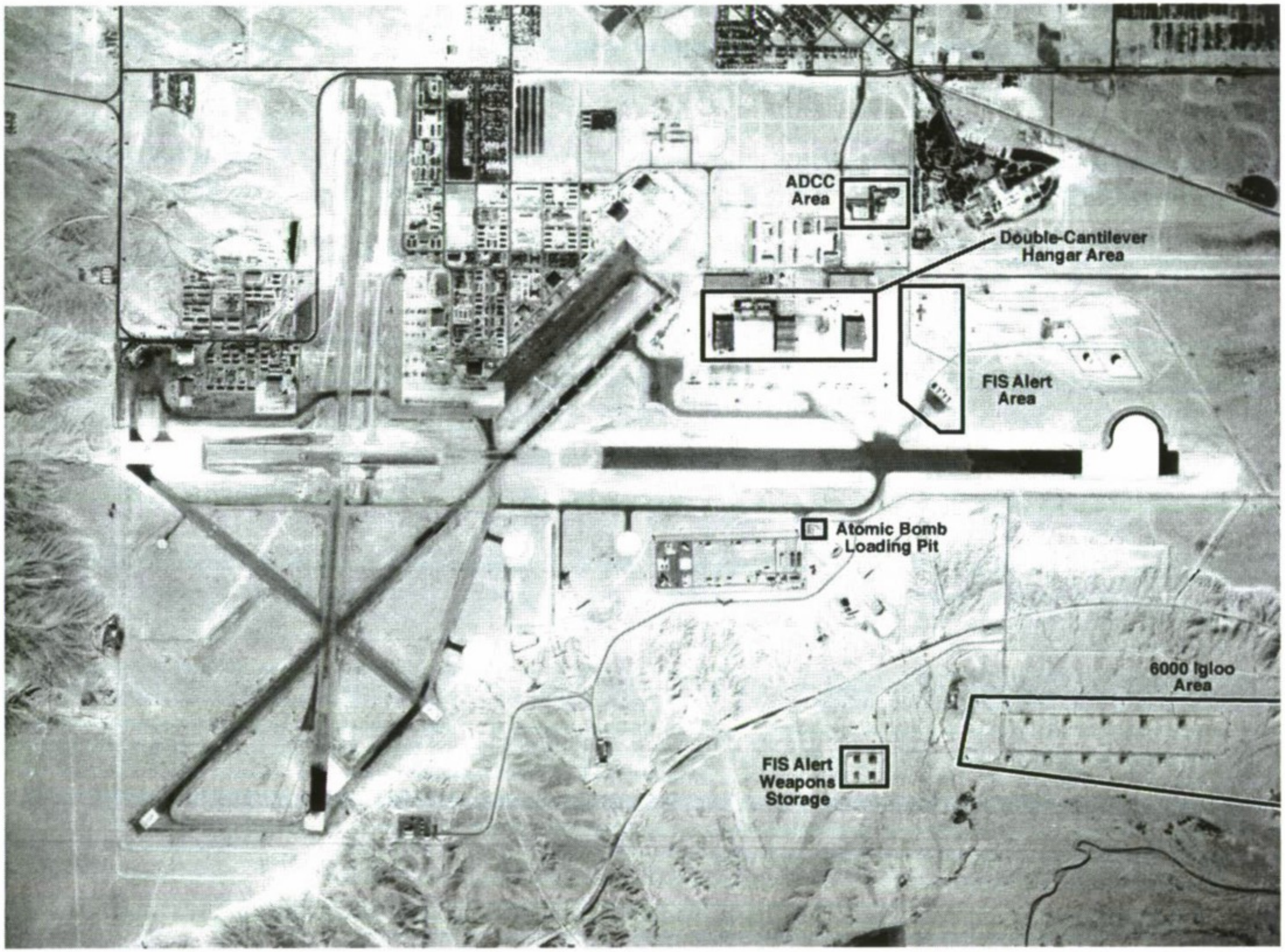

Plate 104: **Aerial View of Kirtland Air Force Base, November 1954. Middle center: Atomic Bomb Loading Pit, 1945 (today gone). Lower right: 6000 Igloo Area, 1946. Upper center, right: ADCC and support structures (Buildings 909-913), 1949-1951. Middle center, left to right: Kuljian double-cantilever hangar (Building 1000), Pacific Iron and Steel double-cantilever hangar (Building 1001), and Kuljian double-cantilever hangar (Building 1002), 1951-1954. Middle center, with the double-cantilever hangars: 4925th Test Group (Atomic) (Buildings 1017-1020), 1952. Middle right: 1st FIS alert area (Buildings 1028-1030), 1951-1953. Lower center: FIS Alert Interim Rocket Storage (Buildings 745-748). Annotations added. Courtesy of the 377th Air Base Wing History Office, Kirtland Air Force Base.**

At nearby Kirtland Field, Army personnel had augmented the original loading pit for the atomic bomb in December 1945 through the installation of a hydraulic lift.[9]

Both Sandia Base and Kirtland Army Air Base underwent serious improvements beginning in 1947. President Truman had signed the Atomic Energy Act on 1 August 1946, an action which in turn led to the creation of the AEC. On 1 January 1947, the AEC took over management of American atomic weapons projects, continuing efforts previously within the jurisdiction of the Manhattan Project. A civilian organization, the AEC in turn linked to a Military Liaison Committee (policy) and to the AFSWP (operations) to interface with the military. Both the committee and the AFSWP included representatives from each of the Armed Services.[10] To handle long-term storage of atomic (and later, thermonuclear) bomb components, Sandia Base managed Project Water Supply and worked with the AEC and the Department of Defense. Sandia Base contracted with the Kansas City engineering firm of Black & Veatch to design and engineer the specialized facilities—the first in the world built to store nuclear weapons.[11] Black & Veatch had initiated work on the permanent facilities for Los Alamos during 1946, hired at the recommendation of President Truman through a sole-source contract. The firm completed initial drawings for the first two stockpile sites, Manzano Base (Site A) at Kirtland and Killeen Base (Site B) at Fort Hood, Texas, in November 1946.[12]

More efforts for Project Water Supply followed. The total number of atomic bomb storage sites in the continental United States would be 13, built out between 1947 and 1956. Other identical special storage sites were constructed at overseas locations. In the United States, the storage sites were split between six main stockpile sites known as NSSs and seven OSSs. Five of the OSSs were also alert forward sites associated with SAC and were alternately called Q Areas. Black & Veatch engineered Manzano Base as underground tunneled igloos and two subterranean plants built into the granite foothills of the Manzano Mountains. The facility was a main stockpile site (NSS), rather than a Q Area—but Kirtland Air Force Base did have a very early alert FIS and an ADCC (see below and Volume I, Part IV). Manzano Base also supported training duties for other atomic weapons storage units between late 1950 and the end of 1953. Run through the AFSWP and Sandia, the training mission was unlike activities at any other stockpile site in the country. In 1952, Air Materiel Command began to shift its own training mission from Kirtland (and Manzano Base under Sandia) to the 2837th Specialized Depot Group at Kelly Air Force Base in San Antonio. In January 1953, the command created the Directorate of Special Weapons at Kelly, and the training mission for duties at NSS and OSS areas completely transferred from Kirtland to Kelly (and from its association with Manzano Base to one with Medina Base, which was the Site K NSS of the special weapons storage program) (see Volume II, Chapter 7). The 1950-1953 training mission at Kirtland led to a brief-lived military unit, the Aviation Field Depot Squadron. About 19 of these squadrons existed, all subordinate to Kirtland. They included not just the transition units assigned to some NSS and OSS areas in the continental United States, but also OSS areas at overseas bases. These squadrons physically trained at Manzano Base and reported to Headquarters Air Force. After becoming operational at their assigned final locations, the Aviation Field Depot Squadrons reported to SAC under new designations.[13]

Manzano Base was minimally operational in late 1949. (The second storage site, Baker, was the first to become operational in 1948 as Killeen Base adjacent to Gray Air Force Base neighboring Fort Hood in Texas; Manzano Base was third behind Site Charlie. Charlie was alternately known as Clarksville Base and was sited at Fort Campbell in Kentucky.) These first three atomic weapons storage areas, Sites A, B, and C, were the only such facilities to include structures built below ground (plants and igloos). The timing of their design and construction exactly paralleled that for Air Materiel Command's underground pilot plant project, undertaken by architect J. Gordon Turnbull (see Volume I, Part III). As of about 1951 (from Site D forward), the remaining atomic weapons storage areas featured only aboveground and heavily bermed buildings, with the exception of the

sporadic construction of one type of nuclear materiel storage structure of 1954. Additions to Manzano Base continued into 1958. The complex was a self-contained special weapons storage facility.[14] Black & Veatch's designs for the remaining atomic bomb storage sites featured both earth-covered and -bermed reinforced concrete igloos and plants, as well as thick-walled and roofed aboveground reinforced concrete storage facilities—the most notable of which were the A Structures. The A Structure stored the plutonium pits for atomic bombs. The A Structures were unusual buildings with reinforced concrete walls and underlying slabs 10 feet thick and false upper stories 17 feet thick in their design of 1950 and 12 feet thick in a second-generation design of 1954. Black & Veatch designed these structures as faux-administration buildings, articulated with false windows on the solid-concrete upper stories. In at least some cases, the A Structures were configured to look like empty concrete pads from the air (as at Fort Campbell for Clarksville Base). Some NSSs and OSSs had A Structures of both the 1950 and 1954 type, while others had only the first-generation A Structures. In addition, the three underground storage sites of Manzano, Killeen, and Clarksville Bases each featured special igloos that were converted as A Structures. These igloos were fully below ground and each included a rear interior four-room area identical to that of the standard A structure. The total number of A Structures at Manzano Base is eight, with other important specialized buildings in the overall compound not discussed here.[15] Manzano Base is a discrete area at Kirtland (an administration area, including Buildings 30113-30145, and the munitions storage compound, including buildings in the 37000 series).

While Sandia Base was in its initial construction phases at the former Oxnard Field, the Army Air Forces began upgrading Albuquerque Army Air Base to accommodate an interrelated atomic weapons mission. As of March 1946, SAC managed the installation, with the major activity the participation of the Army Air Forces in Operation Crossroads in the Pacific. For that test of mid-year, Kirtland personnel modified B-29s to carry the atomic bombs required for the series of detonations. Taking charge of the installation in December 1946, Air Materiel Command formally established the nuclear weapons mission on site, with members of the 509th Composite Wing detached from Wendover to Kirtland. In a furthering of interactions between the Air Force, the AEC, Los Alamos, Sandia, and the AFSWP, Headquarters Air Force set up the Air Force Tactical and Technical Liaison Committee at Kirtland, a committee initially sustained at seven members and expanded to 30 men over time.[16] The committee served as a field extension of the Atomic Energy Division subsumed beneath the Deputy Chief of Air Staff for Research and Development, titled the United States Field Office for Atomic Energy as of July 1948. The United States Field Office for Atomic Energy, like its predecessor located at Kirtland, maintained both scientific and technical liaison with the AFSWP and the operating levels of the AEC through the Los Alamos and Sandia laboratories. Key components of the 1948-1949 mission of the United States Field Office for Atomic Energy included provision of facilities for permanent links among SAC, ADC, and other Air Force commands for nuclear weapons matters; maintenance and operation of a "technical library on all data pertinent to Air Force participation in the Atomic Energy Program;" strong, sustained ties to Los Alamos and Sandia; and, broad technical supervision for special weapons programs.[17] Air Materiel Command maintained a building at Kirtland Field for atomic weapons assembly under the oversight of the AFSWP.[18] Teams of enlisted men built the bombs used in the series of atomic and thermonuclear tests conducted in the Marshall Islands during 1948-1954, including Operations Sandstone (1948), Greenhouse (1951), Ivy (1952), and Castle (1954). They provided this same service for atomic detonations at the Nevada Proving Grounds (later, Nevada Test Site / Nevada Test Range) in 1952.[19] In mid-January 1948, Kirtland Field became Kirtland Air Force Base. The most immediate challenge faced by the base was the improvement of its facilities for the B-36.

The B-36 arrived at Kirtland in September 1948.[20] The bomber weighed 300,000 pounds—more than twice the tonnage of a loaded B-29. Designers for the aircraft focused their attentions on improved landing gear to better distribute the enormous weight of the bomber. Army engineers initiated

immediate experiments for runway and apron pavements. They compacted base courses, tested shear strengths in soils, and redesigned concrete and asphalt overlay mixes. Three basic problem sets existed: (1) determining which existing runways *might* land the B-36 and allow its take-off—either periodically or steadily; (2) strengthening existing runways through asphaltic concrete overlays and second-story concrete slabs; and, (3) designing and engineering entirely new runways for the bomber. The latter solution, the best in the group, was one that the Air Force did not typically enact until about 1954, with the exception of the major new SAC B-36 base of Limestone (later renamed Loring) in Maine, under construction in 1948. The Army Air Forces' first steps to meet the challenge included an Air Forces Installations Directory, produced by mid-1944, that ranked the strength of runways at more than 600 airfields. As engineers discovered, another complication in assessing individual runways was the difference between design strength and actual strength. In most instances, however, Army engineers beefed up runways where the Army Air Forces anticipated the B-36. The University of California, under contract to the Army Corps of Engineers, began concrete overlay tests at Hamilton Field north of San Francisco by July 1944.[21] Eglin Field in Florida completely renovated its main runway in 1945, extending it from 6,000 to 10,000 feet, widening it from 150 to 300 feet, and providing the entire infrastructure with a much different foundation system. (The experimental B-36 arrived at Eglin in 1947 for proof testing.)[22] As of 1948, engineers also undertook major runway redesign at Rapid City (later, renamed Ellsworth) Air Force Base in South Dakota.[23]

At Kirtland, improvements by mid-September 1948 included a variety of overlays atop substantial base courses. The 10,000-foot runway, very long for World War II, featured a 200-foot width and three types of pavement sections. The mid-section, required to be the most substantial portion of the runway in order to accommodate the B-36, featured a nine-inch base course overlaid with 3.5 inches of asphaltic concrete. Other major sections of the primary runway employed an 11-inch base course, topped by 1.5 inches of asphaltic concrete, and a nine-inch base course, topped by two inches of asphaltic concrete.[24] Available sources for the 1948 runway at Kirtland do not indicate the subgrade below the base grade—another critical factor for runway engineering for the B-36. During 1954, ARDC completed two of the world's longest runways: at Kirtland and Edwards Air Force Bases, respectively. The "rebuilt" 13,773-foot east-west runway at Kirtland was 300 feet wide. The runway had a subgrade of compacted earth 17 to 20 inches thick; a base grade of compacted gravel and stone eight to 13 inches thick; and, a top four-inch layer of asphalt overlay. Engineers designed the 1,000-foot ends of the runway for construction in reinforced concrete, to a depth of 15 to 19 inches. The 10,000-foot north-south improved runway of the late 1940s (constant at 200 feet wide) remained in use, along with a second 10,000-foot northeast-southwest runway (at 150 feet wide) (see Plate 104).[25] ARDC engineered Kirtland's primary runway at 13,773 feet in part to offset Albuquerque's elevation at 5,320 feet. The B-52, entering Air Force inventory in the middle 1950s, needed the more extreme length for landing and take-off to counterbalance the effects of altitude.[26] In comparison, the simultaneous state-of-the-art runway at Edwards was 15,000 feet long and 300 feet wide. A reinforced concrete structure, the Edwards runway was 17 to 19 inches thick. The dry lake bed offered an extremely hard subgrade, while the natural landing surface at the end of the runway extended it to 16,800 feet during most of the arid year (see Volume II, Chapter 3).

As the 1940s concluded, a special weapons mission continued to unfold at Kirtland. In December 1949, the Air Force elevated the mission to an independent command level with the formation of the Special Weapons Command and its placement at the installation. Special Weapons Command was the ninth major command activated by Headquarters Air Force in its first years. During the early 1950s, before ARDC became the host command at Kirtland, the Air Force expanded the concept of special weapons to include both biological and chemical munitions, a development with roots in Air Materiel Command experimentation during late World War II (see Volume I, Part III). The biological-chemical warfare mission for the Air Force stayed at Wright-Patterson through 1949, but as of 1950—when ARDC was in its formative stages, but not yet a formal command—the Air Force

grouped the biological-chemical munitions mission with that of atomic weapons and placed all three within Special Weapons Command at Kirtland. The dispensation of the triumvirate of atomic-biological-and-chemical (ABC) weapons remained unstable, however, and multiple short-term shifts occurred during 1950-1951. With the activation of ARDC in 1951, the three key installations involved in biological-chemical weapons research and test became Eglin, Edwards, and Holloman Air Force Bases, with Kirtland maintaining an administrative role. Kirtland was also instrumental due to its proximity to the White Sands Missile Range, the Army proving ground in southern New Mexico where a number of Kirtland tests for special weapons studies took place (see Volume I, Part III).

Simultaneous with its assignment under Air Force Special Weapons Command, Kirtland received a strongly related tenant mission for ADC. The central New Mexico region was an extremely high priority for air defense in the earliest Cold War years due to the presence of the Los Alamos and Sandia laboratories, and to the limited stockpiling of atomic bombs concentrated at Manzano Base. The infrastructure for an elaborate ADC command and control network had been in planning at Headquarters Air Materiel Command in 1948 (see Volume I, Parts III and IV). The next year, Holabird, Root & Burgee, a prominent architectural-engineering firm in Chicago, designed two levels of air defense command post, the ADCC and the Air Defense Direction Center (ADDC), as well as the accompanying radar stations and ancillary buildings. The overall ADC network of 1949 featured 11 ADCCs. By the middle 1950s, ADC added another five ADCCs to fill out the command post network while awaiting the computer-automated SAGE system. The ADCCs and ADDCs were highly specialized buildings that were proto-hardened and designed for limited protection from atomic, biological, and chemical attacks. As such, the structures were among the very first of their kind and represented a major civil engineering achievement (see Volume I, Part III). ADC established air defense areas across the continental United States in July 1948, beginning with just four large regions. By February 1950, however, air defense sectors increased to five key areas within two east-west jurisdictions and one very unusual area at Albuquerque. The air defense area for the 81st Fighter Wing at Kirtland lasted only a short while, superceded by the Albuquerque Air Defense Sector and then by the 34th Air Division (Defense) (see Volume I, Plates 73-77). ADC soon placed a formal ADCC on Kirtland. The Kirtland ADCC was under construction in late 1950 and operational before the close of 1951—one of the first in the nation. Similar to configurations at other Air Force bases, Kirtland also supported an AC&W radar squadron on base (the 690th) in temporary Jamesway huts. For a brief period during 1950, ADC remained undecided as to whether the ADCC for the entire southwestern region should be located at Fort MacArthur (now part of Los Angeles Air Force Base) or at Kirtland. Command decisions resolved that dilemma with two ADCCs: one at Kirtland and one at Norton Air Force Base in Southern California (see Volume I, Part IV and Volume I, Plates 78-79).

The ADCC at Kirtland, the westernmost section of Building 909, is the standard Holabird, Root & Burgee Type 4 Operations Building, with gas-proofing filters and decontamination showers (Plate 105) (also see Volume I, Plate 79). Typically, a small independent power station accompanied the ADCC, along with a Type 3 Operations Building (which served as ADC administrative headquarters for the air defense division). The multi-building air defense command post for the 34th Air Division (Defense) at Kirtland, however, is somewhat different from the national pattern. The compound evoked the relative isolation of the secured facility, its early construction, and the lack of general support facilities on base in 1950. While the ADCC is standard in all of its details, its drawings designate the structure as "Bldg. O" ("operations"), not as the "Type 4 Operations Building." In addition, the cluster of seven ADC command post buildings at Kirtland are labeled as "training facilities" on plans and drawings.[27] In November 1950, site plans for the ADC command post at Kirtland included a small gatehouse (guard station), the ADCC (the Type 4 Operations Building / Building O), a power station, and an undeciphered third structure. A security fence surrounded the property, with locked entrance gates.[28] ADC located the power station (Building 910), labeled on the

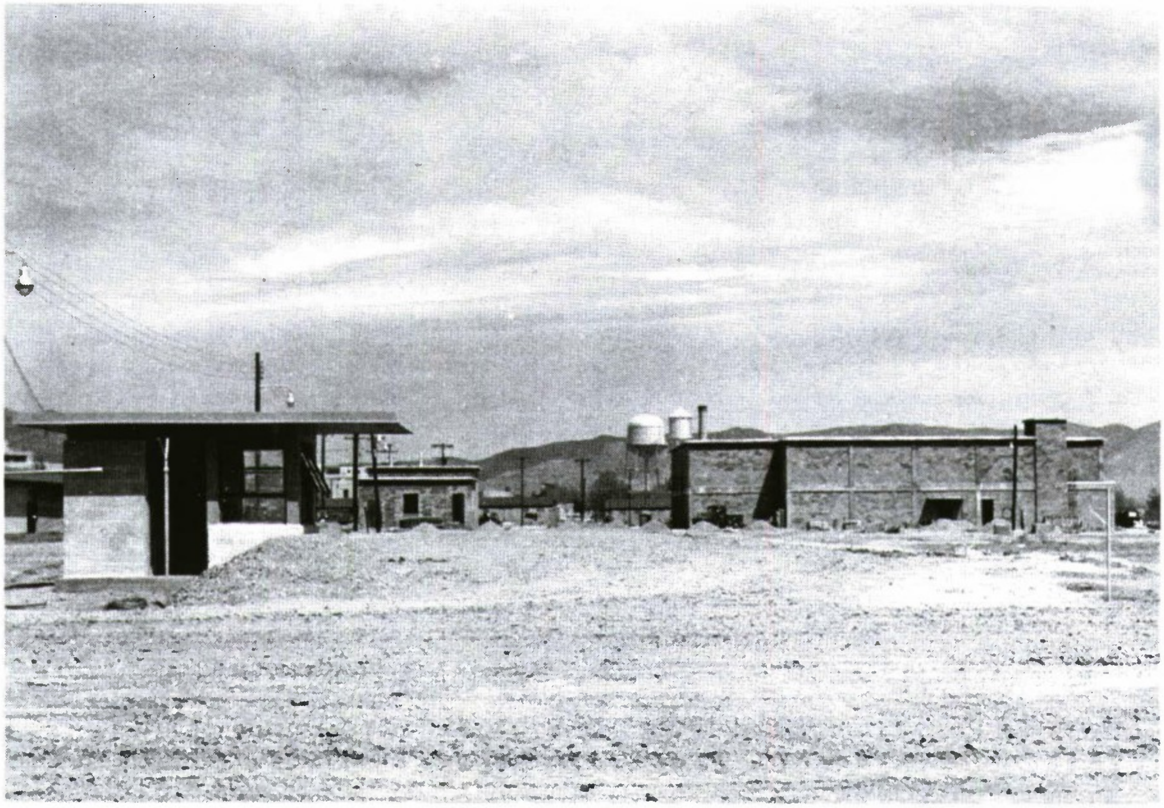

Plate 105: Holabird, Root & Burgee. ADCC (Type 4 Operations Building) for the 34th Air Division (Defense) (Building 909), Kirtland Air Force Base, right. Guard station (demolished) and ancillary structures (Buildings 910-913), left. Designed 1949, constructed at Kirtland in 1950-1951. In *Historical Data 34th Air Division (Defense) 1 January – 31 March 1951.*

drawings as the "Bldgs. P-1 & H" ("power and heating"), between the two other structures (see Plate 105).[29] While all ADCCs and ADDCs included independent power stations, the one for the 34th Air Division (Defense) at Kirtland is not the standard Holabird, Root & Burgee structure, but instead is a similar building designed through the Army Corps of Engineers. This particular deviation from the typical ADCC does occur elsewhere, but is rare. At Kirtland the power station is very small and is a scaled-down version of the standard design. The third structure (Building 911), labeled as "Bldg. 'S'," is a concrete block structure with two oversized wood-paneled loading doors and no windows (see Plate 105). Designed by Holabird, Root & Burgee, "Building S" is likely a warehouse ("storage").[30] Holabird, Root & Burgee designed a full complement of possible cantonment buildings to accompany the ADCC and ADDC, with most (as with "Building S") completed in August and September 1949, before final design of the Type 1-4 Operations Buildings (see Volume I, Part IV and Volume II, Chapter 13).

The final three structures filling out the ADCC area for the 34th Air Division (Defense) were a Corps-designed auxiliary power station combined with a "chlorinator building" and two small houses for military personnel. The added power / chlorinator building suggests the need for both enhanced independent power facilities and a special decontamination unit for water supply. The concrete block structure (Building 888) used chlorine gas. It was located immediately adjacent to the two on-site residences. The presence of a chlorine gas decontamination unit may have been unique to the ADCC cluster at Kirtland.[31] The two concrete-block houses, each approximately 775 square feet, featured a

single bedroom, study, living room, and bath, with no kitchen. Labeled "Building 'GQ'," on the drawings, the houses (Buildings 912 and 913) were also designs of Holabird, Root & Burgee (from mid-September 1949), constructed at Kirtland in January 1951.[32] "GQ" likely referenced "general quarters." The bare-bones amenities in the houses indicate that the stationed ADC military personnel shared mess facilities with officers on base. No other ADCC known to the author included this type of housing, although the existence of a standard Holabird, Root & Burgee design for the structures indicates that Air Materiel Command had anticipated such a need at some installations. (At Tinker Air Force Base in Oklahoma, for example, rows of Holabird, Root & Burgee airmen dormitories provided housing for a combined ADCC and ADDC at a collocated site just off base. See Volume I, Part IV and Volume II, Chapter 13.) The seven-building ADCC cluster at Kirtland remained intact only for a brief period. The gatehouse was gone by 1957, while the base removed the combined auxiliary power and decontamination building (Building 888) between 1957 and 1966 (see Plates 104 and 106).

The ADC network of ADCCs and ADDCs across the continental United States is largely lost to history today. Built between 1949 and 1956, the system overlapped planning and construction for SAGE during 1955-1960. The three SAGE Combat Centers and 23 SAGE Direction Centers replaced the 16 ADCCs and their corresponding ADDCs at AC&W radar stations, obscuring the preceding layer of air defense command and control. At Kirtland, the 34th Air Division (Defense) was active between January 1951 and January 1960, and continued functioning through October 1960 as a manual SAGE Direction Center for the Albuquerque Air Defense Sector.[33] In 1955, ADC had planned for a combined SAGE Combat and Direction Center in Albuquerque, also true for Oklahoma City. In both cases, ADCCs preexisted at Air Force bases in the cities (Kirtland and Tinker).[34] When ADC scaled back its plans for SAGE, a Direction Center at Luke Air Force Base in Arizona took over for Kirtland's ADCC, while that at Richards-Gebaur in Kansas City superceded the ADCC at Tinker. The air defense command network following SAGE returned to a physical adaptation of the late 1940s ADCCs and ADDCs, as the Backup Interceptor Control (BUIC) system (see Volume I, Part IV). The ADCC at Kirtland did not function as a BUIC I, II, or III command post during the 1960s.

In addition to serving as the location for one of the first operational ADCCs for ADC, Kirtland also received one of the very earliest alert FIS squadrons established for air defense of the continental United States. During the late 1940s into 1951, siting for fighter (pursuit) aircraft was haphazard, with deployment at both military and civilian airfields. In 1948, alert aircraft parked at the ends of runways with their crews on duty in makeshift ready shacks. By 1949, an example of an underground fighter crew building exists at Eglin (see Volume II, Chapter 3). After the opening of the Korean War in June 1950, the need to improve FIS escalated, and ADC began to build a network of permanent infrastructure for alert squadrons of fighter aircraft. Personnel stationed in ADCCs scrambled alert FIS based on information gleaned from the AC&W radar stations, the Ground Observer Corps, and other sources nationwide (see Volume I, Part IV). In January 1949, the 81st Fighter Interceptor Wing was in place at Kirtland. The 81st Fighter Interceptor Wing (and, subsequently, the 93rd FIS) was responsible for the air defense area set up to protect Los Alamos and Sandia (see Volume I, Plate 74). A single ADCC controlled multiple FIS within its air defense jurisdiction.[35] As Kirtland's air defense sector grew larger under the 34th Air Division (Defense), it included the southern and eastern parts of New Mexico, and extended into west Texas. In July 1950, Kirtland was one of only 14 priority FIS locations in the continental United States, including two municipal airports. Formal alert status for the FIS at Kirtland occurred in 1951. Early that year, ADC sponsored the first alert hangars for its FIS nationwide, developing four types of hangars between 1951 and 1953 (see Volume I, Part IV). The command erected a bolted, prefabricated structure designed and engineered by Butler Manufacturing of Kansas City at all but two of its initial venues. The Butler hangar was relatively rare in comparison to the more widely built hangar designed by the New York firm Strobel & Salzman. Appearance of a Butler FIS alert hangar always indicates a prioritized mission during the

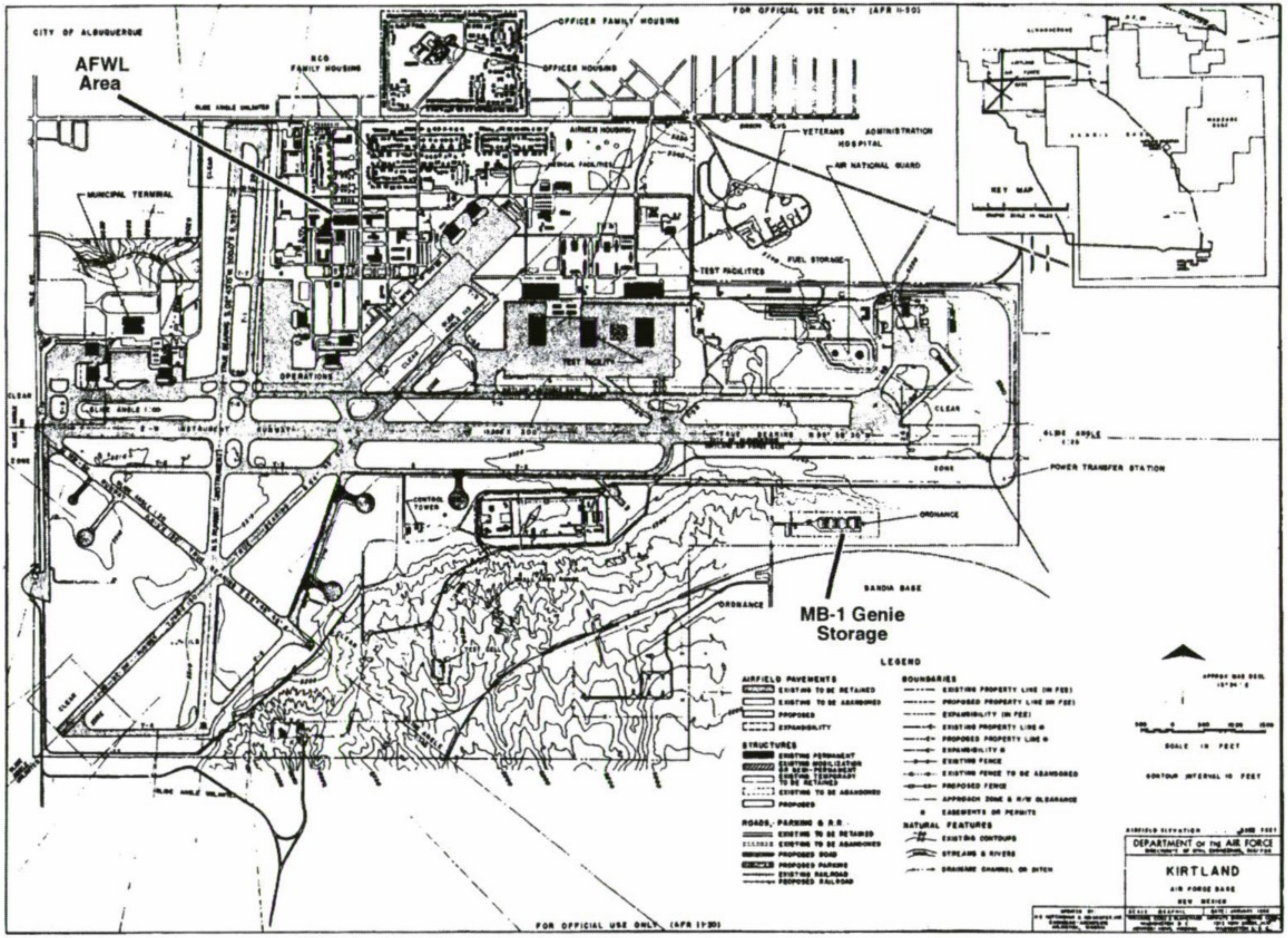

Plate 106: Headquarters United States Air Force, Directorate of Civil Engineering, Master Plan of Kirtland Air Force Base, January 1966. Annotations added. Upper left: AFWL (Buildings in the 400 series). Upper center: ADCC Compound (labeled "Test Facilities") (Buildings 909-913). Middle center: 1st FIS alert area, including remnant of alert apron (Buildings 1028-1029), with KC-135 hot cargo pads. Middle right: 2nd FIS alert area, including moved Building 1030 and added Buildings 1042, 1043, 1045, 1046, 1047,and 1053. Lower right: MB-1 Genie igloos and checkout-assembly unit (Buildings 750-755). Lower center: ALECS (Building 622). Courtesy of Civil Engineering, Kirtland Air Force Base.

early Cold War. A group of ancillary structures also supported FIS alert, including a ready crew dormitory (usually combined with squadron operations), a flight simulator, maintenance hangars, and munitions checkout and storage. At Kirtland, the 93rd FIS was on alert until July 1960 The 93rd FIS completed its mission for ADC simultaneously with the tenure of the ADCC on base. Most often, ADC transferred FIS alert facilities to the Air National Guard (ANG)—the situation at Kirtland. ANG often continued a secondary alert for decades.

Kirtland's alert FIS is an excellent example of the active dynamics of air defense during the 1950s. When its Butler hangar went up in mid-1950, Kirtland did not yet have a lengthened, state-of-the-art runway. ADC always sited FIS alert hangars on a 45-degree taxiway at the end of the primary runway to facilitate fast takeoff. The command also clustered the support structures near the alert hangar and on occasion reused World War II hangars located elsewhere on the flightline for maintenance. When an Air Force installation built a new primary runway, or rebuilt and lengthened an existing runway, the earliest FIS alert infrastructure often illustrated the change. Sometimes, ADC physically moved the Butler hangars, as was the case at Kirtland. Personnel rebolted the hangar at a new site at the end of the extended runway, erecting a second set of support buildings. At Kirtland, the original and subsequent locations of the alert hangar are visible in aerial photographs and on maps (see Plates 104 and 106). Early ancillary structures supporting FIS alert on base were minimal and included a readiness crew dormitory (Building 1029) and a flight simulator (Building 1028), added to support the Butler alert hangar (Plate 107) in April 1952 and December 1953, respectively; and, four interim rocket storage igloos (Buildings 745-748) constructed in late 1953.[36] ADC did not erect a new maintenance hangar for its alert FIS operations at Kirtland at the outset of the 1950s, but instead used one or both of an existing pair of World War II hangars separately located to the west (Buildings 481 and 482). In January 1956, the command prepared a second site at the end of the extended east-west runway for a relocated FIS alert.[37] In addition to reerecting the four-pocket Butler hangar at the location (Building 1030) during 1956-1957, ADC added a new readiness crew dormitory (Building 1047), a maintenance hangar (Building 1043), and a checkout and assembly structure for the folding-fin air-to-air rockets (FFARs) carried by the F (fighter) -86D (Building 1042).[38] Additional generic support structures at the site included a supply and issue shop and an armament shop (Buildings 1045 and 1046). Both the maintenance hangar and the munitions structure were standard for FIS alert of 1953-1954, with the maintenance hangar the second-generation version designed by Strobel & Salzman and the FFAR checkout and assembly structure a single "Unit A" version designed by Weiskopf & Pickworth of New York. By 1956, the Unit A facility was becoming outdated. Guided air rockets (GARs) were beginning to replace FFARs as FIS munitions, and a combined Unit A / B storage structure was the norm. Choice of the Unit A structure as a stand-alone facility is indicative of an air defense mission at Kirtland that was somewhat in abeyance in the middle 1950s—possibly due to runway construction and rebuilding the FIS alert area at a new location, but more probably illustrative of planning toward a future weapons system (skipping over the GAR generation of munitions).

By about 1958, ADC assigned the nuclear-tipped MB-1 Genie, a guided air-to-air rocket carried by the F-89J, the F-101B, the F-102, and the F-106, to the 93rd FIS. Only those FIS alert squadrons of highest priority received the MB-1 Genie. The Genie necessitated construction of a segregated munitions area that included multicubicle magazines and a specialized checkout and assembly structure. Designed and engineered by Black & Veatch during 1955-1956, the munitions facilities appeared at Air Force installations through the late 1950s. Black & Veatch was the only firm designing nuclear weapons storage structures during the 1950s (such as Manzano Base discussed above), and worked very closely with several Air Force commands, the Corps of Engineers, and the AFSWP to establish design and engineering parameters for what amounted to infrastructure without existing models. For the MB-1 Genie (also known as the Ding Dong and Hi Card), representatives of Black & Veatch attended meetings for the design of the multicubicle igloos at Headquarters ADC

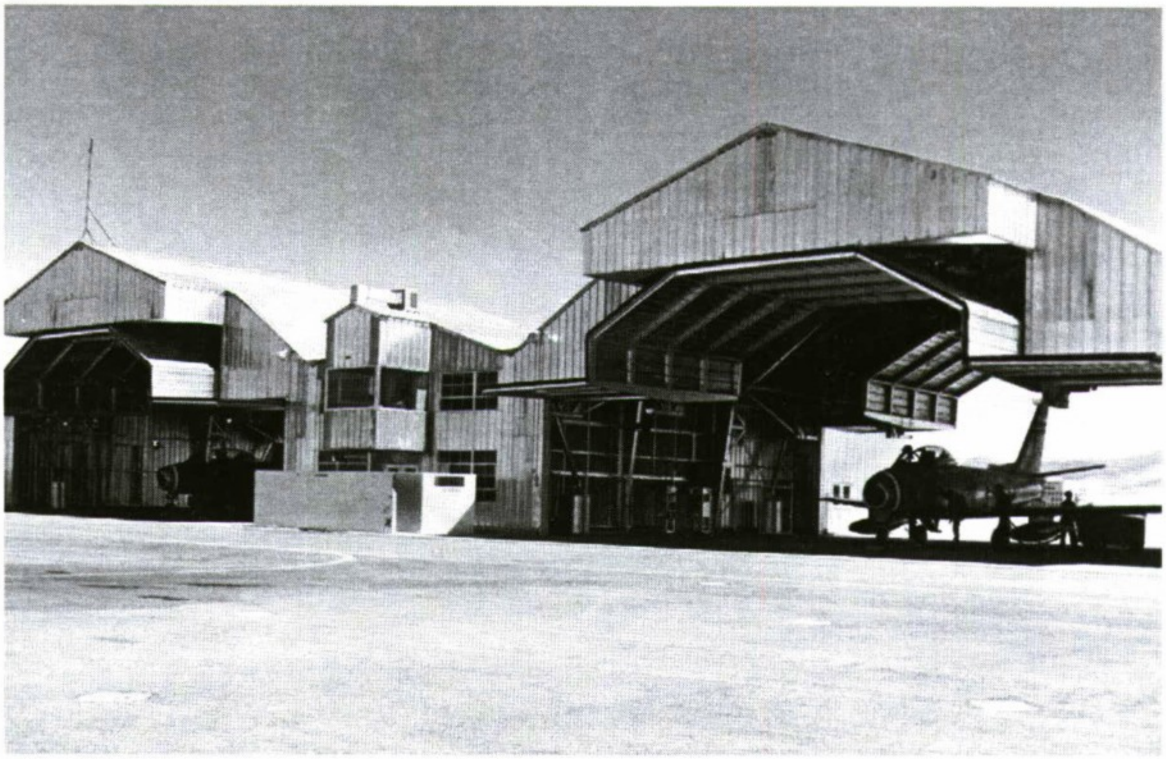

Plate 107: Butler Manufacturing. Four-Pocket FIS Alert Hangar (Building 1030), Kirtland Air Force Base, 1951. View of 1 May 1953. Courtesy of the 377th Air Base Wing History Office, Kirtland Air Force Base.

in Colorado Springs and at the Special Weapons Center at Kirtland during October 1955.[39] At Kirtland, ADC sited the cluster (Buildings 750-755) on the opposite side of the east-west runway from the FIS alert grouping (see Plate 106). The F-101B also necessitated changing the front and rear doors of both the Butler and Strobel & Salzman alert hangars to accommodate the longer fighter aircraft. ADC implemented this change at Kirtland in October 1958 and added a Black & Veatch photoelectric security system for the hangar in May 1959.[40] Yet, the 93rd FIS likely possessed the MB-1 Genie for only a brief period of months during 1960. During the second half of 1959, the squadron supported the F-86L, an upgraded version of the F-86D. The F-86 did not carry the MB-1 Genie. At the same time, an alert FIS at Walker Air Force Base in southern New Mexico received the F-89J (and Genie).[41] The Black & Veatch specialized storage for the MB-1 Genie had been identical for both bases, with Kirtland using the drawings supplied to Walker for its own facilities. As of July 1960, ADC concluded its FIS mission at Kirtland. The New Mexico ANG took over the compound by 1961. The up-and-down quality of prioritized FIS alert for the installation—very high during the early 1950s, average at mid-decade, very high a second time in the late 1950s, and transitioned from ADC to ANG in 1961—is illustrative of the extreme fluidity of air defense during the first decade of the Cold War.

While ADC set up ADCC and alert FIS missions at Kirtland during 1950-1952, Air Force Special Weapons Command sponsored the initial permanent buildings and structures on base. These facilities supported the atomic weapons program. The 4925th Special Weapons Group[42] evolved into the 4925th Test Group (Atomic) by mid-1950. Special Weapons Command assigned B-50s, B-36s, and B-47s to the group, modified to carry atomic bombs.[43] Enhancement of runway pavement and aprons during 1948-1950 for the B-36 temporarily resolved take-off and landing issues at the installation, but did not satisfy pressing needs for large-scale maintenance hangars. The atomic weapons mission at

Kirtland required an unusually large amount of maintenance space within which personnel could both modify bombers to carry the new weapons and could supervise loading atomic bombs onto prepared aircraft. While SAC had sponsored a thin-shell, reinforced-concrete arch maintenance hangar for the B-36 in mid-1947 (built at Ellsworth and Loring Air Force Bases during 1948-1949), by 1950 the Air Force had returned to the drawing board to contract a suitable hangar for its installations. In early 1951, only preliminary design and engineering efforts were in progress for what would become the standard steel double-cantilever maintenance hangar (designed by Kuljian Corporation of Philadelphia) (see Volume I, Part IV and Volume II, Chapters 3, 4, 5, 7, and 10). Mills & Petticord of Washington, D.C., an engineering firm that had handled a variety of standard structures for the Air Force in the late 1940s, developed two prototypical versions of a double-cantilever hangar. The firm's first design dated to January-February 1951, its second to August 1951. Kirtland needed such a maintenance and modification facility immediately, and by April 1951 the base had a variant version of the Mills & Petticord double-cantilever hangar under construction. Mills & Petticord, however, are only known to have completed two sheets of basic drawings for each variation of its early double-cantilever hangars of January-February 1951—a sheet showing overall plan, elevation, and sections, and one showing the proposed door arrangement (critical for entry and egress of the B-36).

The hangar at Kirtland (Building 1001) conforms to the footprint for Mills & Petticord's "expansible medium bomber hangar" of mid-February 1951 (at 380 by 244 feet) and is a very rare structure. The design was considered to be the "intermediate" size for a double-cantilever hangar and could accommodate four B-36s: two on each side with partial tail or nose of the bomber protruding. (Air Force personnel parked B-36s, B-47s, and B-52s in double-cantilever hangars by positioning the aircraft in both nose- and tail-in positions.) The Albuquerque District of the Army Corps of Engineers appears to have requested the baseline Mills & Petticord drawings from the Corps headquarters at Fort Belvoir, Virginia, and, in turn, contracted with the Pacific Iron and Steel Company in Los Angeles to develop a full set of drawings for a double-cantilever hangar to meet urgent needs at Kirtland. The Pacific Iron and Steel Company opted for more conservative engineering than that proposed by Mills & Petticord. The chief differences between the hangar of the Pacific Iron and Steel Company and those of Mills & Petticord (and Kuljian Corporation to follow in October-December 1951) were the use of steel bridge girders (rather than open web-type trusses) for the primary cantilevers and a door height of only 40 (rather than 60) feet. Cantilever length was also much shorter: 66.5 feet rather than the 92-foot transverse trusses of the final double-cantilever hangar standardized for SAC. The shorter cantilever derived from the increased size of the interior shop towers for Building 1001 (each 111 by 61 feet and three stories high) (Plate 108).[44] Initially, the 4925th Test Group (Atomic) used the upper shop floors for storage of project supplies.[45] The Pacific Iron and Steel hangar at Kirtland was notably different in appearance from the standard Kuljian hangar of late 1951: its arches visibly extended above the flat roofline of the structure. The Mills & Petticord double-cantilever hangar August 1951, the firm's second design for the Air Force, also handled roofline treatment in this manner. Both Mills & Petticord hangar designs of 1951 were never adopted by the Air Force except as reconfigured by Pacific Iron and Steel.

Building 1001 was the first double-cantilever hangar constructed for the B-36 and was one of a kind in the United States. An extremely important structure, the hangar had only one known counterpart: the "Pacific Iron and Steel Company Hangar" at Nouasseur Air Base in French Morocco in late 1951 (Plate 109). The Kirtland and Nouasseur hangars were identical in their exterior and interior details,[46] and both were constructed due to the extreme priority of the B-36 and atomic bomb missions at their respective installations. Nouasseur was a key overseas SAC installation that had a special munitions area (an OSS) parallel to Manzano Base at Kirtland.[47] The Pacific Iron and Steel hangar at Nouasseur was a 50-percent larger version of the double-cantilever hangar and included space for six B-36s simultaneously. Pacific Iron and Steel was one of a few firms in the late 1940s that were front-

shaker, and a static test frame. ARDC and its follow-on AFSC also used Building 1001 for training, with classrooms included on upper levels of the shop towers.[52]

During 1953-1955, ARDC added two more double-cantilever hangars for the Special Weapons Center at Kirtland. Bracketing Building 1001, these hangars were of standard Kuljian design for the medium bomber. Kuljian developed three variations of the double-cantilever hangar for the Air Force: in basic (two large aircraft), intermediate (four large aircraft), and large (six large aircraft) sizes. Each of these variations was also possible in an "expansible" form. Use of the expansible hangar, as at Kirtland, implied that the Air Force intended to enlarge the hangars by adding more bays to one side at a future date (only there is no verified example where this has actually occurred). The two Kuljian double-cantilever hangars at Kirtland (Buildings 1000 and 1002) derived from a design updated to December 1952 (Plate 111). The Air Force Special Weapons Center initiated construction for both hangars in June 1953, with sequential completion in March and April 1955. The island shop towers for Building 1002 were the standard three stories high. The Air Force finished those for Building 1000 for only one floor of shop space each. The 4925th Test Group (Atomic) occupied all three double-cantilever hangars at Kirtland. The 4927th Test Squadron was assigned to Building 1002, while the 4928th Test Squadron and the 4924th Armament and Electronics Maintenance Squadron occupied Building 1000.[53] The Special Weapons Center added a photographic laboratory alongside Building 1000 in early 1956.[54] While selected Air Force bases did support the largest version of the double-cantilever hangar (for work on up to six B-36s simultaneously) and a few constructed a pair of the medium double-cantilever hangars (for work on eight B-36s simultaneously, or on the B-47 or B-52), no other base is known to have three double-cantilever hangars on its flightline.[55] ARDC assigned the Special Weapons Center its first projects to install nuclear weapons in bomber and fighter-bomber (B-45) aircraft in Building 1001 in November-December 1952, with efforts underway in 1953. Initially, the marriage projects attempted to achieve a successful mating of a particular atomic bomb (with bombs in continued development) in all versions of bombers and fighter-bombers (the B-29, B-50, B-36, B-47, and B-45 during this period). By early 1953, however, the Special Weapons Center began to tailor aircraft-weapons projects to individual aircraft. ARDC established requirements for 16 bomber-nuclear weapon combinations. Retrofitting state-of-the-art atomic (and then thermonuclear) bombs to older bombers was especially difficult as Los Alamos weapons scientists improved the bomb.[56]

During 1953, too, the Air Force, Army, and Navy made more decisions regarding responsibilities for the research, development, testing, and evaluation of the types of training equipment needed for nuclear weapons. The Wright Air Development Center at Wright-Patterson worked with the Navy on the task of developing training equipment for fission weapons. The Naval Weapons Evaluation Facility moved into Building 1002 at Kirtland in early 1956, from previous temporary hangar space in Building 401. Their work area in Building 1002 expanded in July 1964.[57] Personnel at the Aeronautical Systems Division (a follow-on to the Wright Air Development Center) worked on Project 6090 to design a trainer for fighter-delivered atomic munitions, while ARDC assigned development of an atomic bomb simulator to the Special Weapons Center at Kirtland (Project 67750).

> The atomic bomb simulator was a necessity for realistic training. In view of the hazardous and complex nature of nuclear weapons and their differences, as compared with conventional munitions, extensive indoctrination had to be given to personnel who would be handling and operating them to insure safe and effective procedures. On-the-job experience, using actual devices, was usually an important method of training; however, such use of actual nuclear weapons for training was uneconomical and inadvisable. Therefore, for use as a training aid, the Special Weapons Center began

Plate 110: 4925th Test Group (Atomic), Bomb Navigation Systems (Building 1018), Kirtland Air Force Base. View of 15 April 1953. Courtesy of the 377th Air Base Wing History Office, Kirtland Air Force Base.

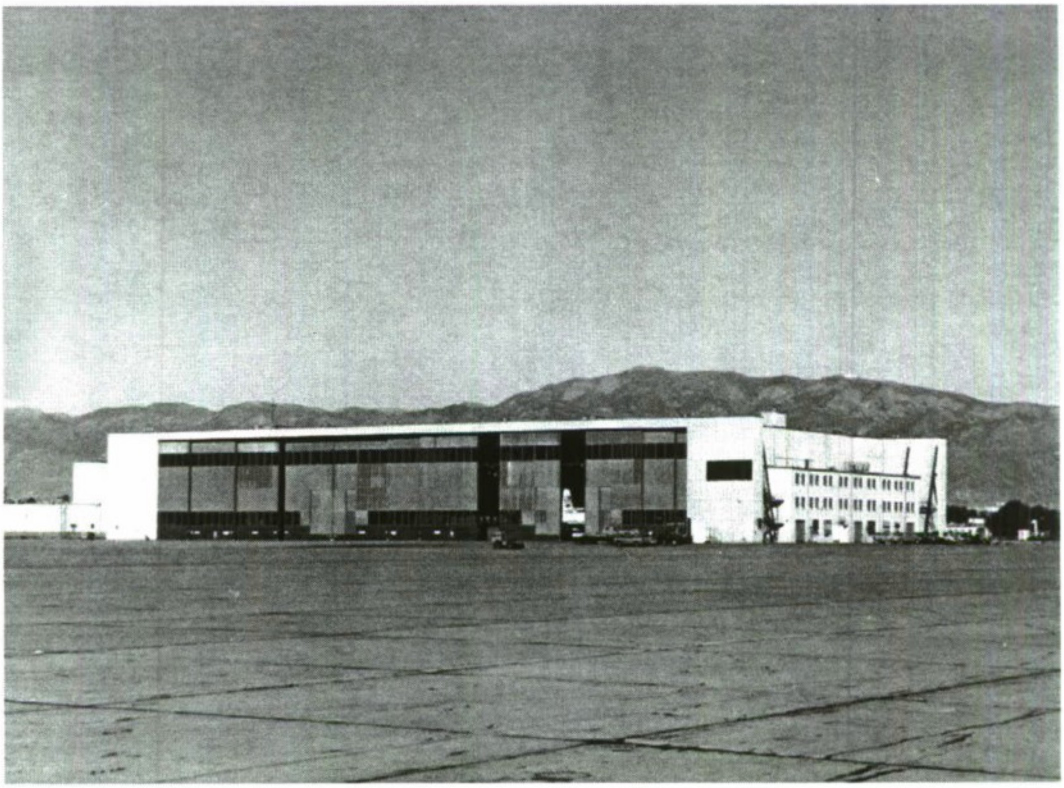

Plate 111: Kuljian Corporation. Medium-Bomber Double-Cantilever Hangar (Building 1002), Kirtland Air Force Base, 1952. Undated view. Courtesy of the 377th Air Base Wing History Office, Kirtland Air Force Base.

> development of equipment to be substituted for an operational bomb. The equipment would consist of an electronic unit capable of simulating all functions and malfunctions of all atomic weapons currently in existence, causing all the reactions at the monitoring panel that would normally be received from an actual bomb during storage, inspection, loading, and flight.[58]

Training equipment developed by the Special Weapons Center at Kirtland was next assigned to the Directorate of Special Weapons at Kelly for stocking in a special warehouse there (see Volume II, Chapter 7).

Although the training mission for duties at the NSS and OSS areas had shifted from Kirtland to Kelly during 1952-1953 (see above), some training missions related to nuclear weapons remained at Kirtland. The first training programs at Kirtland focused on delivery of the atomic bomb. Training for SAC B-36 crews in the delivery of a thermonuclear bomb began at Kirtland in early October 1953. ATC ran the three-week courses, with three SAC crews per class. ATC initiated the program for B-47 crews at Kirtland in December 1954. During 1955 and 1956, ATC moved training for the thermonuclear bomb to Lowry Air Force Base in Colorado, and subsequently to McConnell Air Force Base in Kansas. Training for RB (reconnaissance bomber) versions of bombers shifted to Randolph in San Antonio. The Air Force converted bombers to RB aircraft to take aerial photographs and gather information. In March 1956, ATC combined atomic and thermonuclear bomb training into a single three-week course. The command later streamlined the course to 10 days. ATC ran courses for 12 SAC crews per week during these years. By mid-March 1956, the command had trained more than 2,000 SAC officers and airmen for the B-47 (698 three-man crews), as well as 391 B/RB-36 crews (16-man crews). (Crew sizes for the B-36 and B-47 were radically different, with that for the B-36 very large.) ATC continued training for the B-52. Even with these training figures however, in April 1956 "there were more TN [thermonuclear] -capable aircraft available than TN-trained aircrews to fly them." By 1957, SAC had the aircraft, the bombs, and the trained crews to deliver "both atomic and thermonuclear weapons on a mass scale."[59]

Among the research, development, testing, and evaluation responsibilities of the Air Force Special Weapons Center at Kirtland during the 1951-1954 years was participation of the 4925th Test Group (Atomic) in aboveground atomic and thermonuclear tests in the Pacific and at the Nevada Proving Ground (later, Nevada Test Site). Tests of 1951 were Ranger and Buster / Jangle (Nevada) and Greenhouse (Eniwetok Atoll, Marshall Islands); of 1952, Tumbler / Snapper (Nevada) and Ivy (Eniwetok); of 1953, Upshot / Knothole (Nevada); of 1954, Castle (Eniwetok and Bikini Atolls, Marshall Islands); and, of 1955, Teapot (Nevada). The tests were of varied duration and some included multiple test shots. For example, Upshot / Knothole included 11 live atomic tests that were configured as bomb drops from a B-50, B-47, and B-36, and as detonations on 100- and 300-foot test towers. The Mike shot of Ivy, on November 1952, was the first thermonuclear detonation. In addition to these broad missions, the 4925th Test Group (Atomic) provided flying laboratories to gather airborne data on test results, piloted and drone aircraft to sample radioactive clouds, safety aircraft to measure radioactivity in the areas surrounding tests, nuclear cloud-tracking aircraft to establish fallout patterns, and terrain survey helicopters.[60] To support the aboveground nuclear testing at the Nevada Proving Ground, the Air Force Special Weapons Center also received management jurisdiction for Indian Springs Air Force Base in July 1952. Indian Springs was adjacent to the test site in Nevada. The Special Weapons Center maintained control of Indian Springs into 1961.[61] Aboveground nuclear tests in the Eniwetok and Bikini Atolls during 1956 each received American Indian tribal names: Redwing, Cherokee, Zuni, Yuma, Erie, Seminole, Flathead, Blackfoot, Kickapoo, Osage, Inca, Dakota, Mohawk, Apache, Navajo, Tewa, and Huron.[62]

Both the Development and Research Directorates of the Air Force Special Weapons Center took on vital roles as the nuclear weapons mission unfolded during the first half of the 1950s. Working with the Wright Air Development Center at Wright-Patterson, the Development Directorate sustained responsibility for a variety of nuclear weapons projects, including Brass Ring (1952), Caucasian (1952-1954), Cornrose (1953), Rocky Mountain (1953), Heavenbound (1953), and Barroom (alternately, Cauterize) (1953-1954). Each of these efforts illustrated the intensity of the earliest Cold War atomic weapons studies, and their relationship to goals of specific target effectiveness and detonation conditions. Caucasian was a special munitions package that required some type of unmanned delivery. Brass Ring was a delivery scenario for Caucasian that evaluated the feasibility of firing the Navaho guided missile (with a Caucasian warhead) from an unmanned B-47, or from a B-47 flown manually but abandoned by its crew at a certain point in the mission.[63] Cornrose analyzed the adaptation of nuclear weapons for destruction of massive dams and harbor infrastructure. Rocky Mountain addressed cryogenics (and used the –200 degrees Centigrade environmental test chamber in Building 1001), while Heavenbound looked at the possibilities of high-altitude detonation of nuclear weapons for air defense (which would lead to the MB-1 Genie). For Heavenbound, the AEC, the Sandia and Los Alamos laboratories, ADC, and ARDC's Cambridge Research Center at Hanscom Air Force Base in Massachusetts were each strongly interested in the study results. During 1954, the Air Force Special Weapons Center supported the construction of facilities at Kirtland exclusively for Project Cauterize.[64] The Research Directorate of the Special Weapons Center began a weapons data indexing project as of 1953. The Special Weapons Center continued to maintain a technical library "containing all data pertaining to the participation of the Army Air Force [*sic*] and the United States Air Force in the atomic energy program."[65]

ARDC assigned the Air Force Special Weapons Center its first nuclear missiles developmental responsibility for an atomic warhead for an air-to-air rocket in mid-May 1954. Eight months earlier, the AEC and the Special Weapons Center had signed a memorandum of understanding that delineated defined areas of cooperation for nuclear warhead-missile projects.[66] The Special Weapons Center issued $20,000 contracts to four companies for the atomic air-to-air rocket, funding their proposals for development of a final weapons system. Douglas Airplane Company, Consolidated Vultee Aircraft Corporation (the manufacturer of the B-36), McDonnell Aircraft Company, and Lockheed Aircraft Corporation each participated. The Special Weapons Center retained Ramo-Wooldridge Corporation as a technical consultant on a cost-plus-fixed-fee basis. Ramo-Wooldridge was concurrently the managing contractor for the Western Development Division, the progenitor of ARDC's Air Force Ballistic Missile Division (AFBMD) and ultimately Los Angeles Air Force Base (see Volume II, Chapter 9). The Special Weapons Center awarded the contract for development of the nuclear-tipped air-to-air rocket to Douglas in January 1955.[67] (And by mid-year, discussions were underway with Black & Veatch for design of the special multicubicle magazines needed to store the rocket [Buildings 750-755 at Kirtland].) Research, development, testing, and evaluation for nuclear missiles expanded as a mission at Kirtland throughout the 1950s, becoming the major emphasis of the Air Force Special Weapons Center by the early 1960s. The day following ARDC's assignment of the MB-1 Genie to the Special Weapons Center in May 1954, the command completed the design release for the XW (experimental weapon)-5 warhead for the Matador guided missile, and shortly thereafter received a notice that the Snark would carry the Class C XW-15-X1 warhead. By August, the Air Force designated the Rascal for the Class D XW-15-X1 warhead. Missiles work accelerated with efforts for the Navy's Talos warhead in September, as well as through planning for the installation of the XW-7 atomic warhead on the Crossbow. Atomic warhead work went forward for Bomarc with the XW-40 as of March 1956. In September, ARDC activated the 4950th Test Group (Nuclear) at the Special Weapons Center, a tacit recognition of the full shift from atomic bombs to a family of atomic and thermonuclear weapons systems.[68]

Another major development for the increasingly sophisticated mission at the Air Force Special Weapons Center also occurred in 1956. ARDC moved the [Nuclear] Blast Effects Research Group at Wright-Patterson to the Special Weapons Center at Kirtland. The Blast Effects Research Group derived from the Special Studies Office originally established within Air Materiel Command at Wright-Patterson in 1950 (which had been an outgrowth of the AFSWP Protective Construction Committee of 1947-1948). The Special Studies Office at Wright-Patterson had focused on structural engineering issues for protective construction, relevant to Air Force needs in a nuclear world. In 1950, the Special Studies Office had hired Austrian engineer Eric H. Wang, a brilliant engineer-mathematician who led what became the Protective Structures Group within the office. The Special Studies Office participated in atomic and thermonuclear weapons testing, beginning with Operation Greenhouse in 1951. During that year, Mr. Wang's analytical team additionally included Russian scientist Roman Birukoff. The evolution of Mr. Wang's Special Studies Office is complex within the bureaucratic organization at Wright-Patterson during the early 1950s, but unfolded to include critical contracted studies through the Armour Research Foundation in Chicago. During 1954, the Armour Research Foundation built one of the first shock tubes to simulate atomic shock wave propagation in Gary, Indiana—a structure 150 feet long and six feet in diameter. Armour operated the shock tube for the Air Force, with experiments at the facility subsumed under Project 1080, "Nuclear Effects on Hardened Structures (Protective Construction)." Eric Wang's Blast Effects Research Group at Wright-Patterson managed Project 1080. They moved the effort to Kirtland under the Structures Division of the Research Directorate of the Air Force Special Weapons Center, but continued to use the Armour shock tube in Gary. Both Eric Wang and Roman Birukoff relocated from Wright-Patterson to the Special Weapons Center in 1956 (see Volume I, Part III).

The Structures Division of the Research Directorate of the Special Weapons Center at Kirtland evolved into the key Air Force unit that concentrated on civil engineering projects related to nuclear weapons effects. Interactions with universities and foundations to support the pioneering research of the Structures Division were many, and projects were interwoven and complex (see Volume I, Part III). Mr. Wang's group worked closely with Dr. Nathan M. Newmark of the University of Illinois. Dr. Newmark had provided the Army Air Forces structural engineering expertise from as early as 1945, when Dr. Theodore von Karman had selected him as one of the authors for a volume in *Toward New Horizons*. In the late 1950s, Dr. Newman and his associates at the University of Illinois drafted successive Air Force design manuals on nuclear protective and hardened construction. Throughout the next decade, the Air Force funneled its civil engineers working with nuclear weapons effects to a program of graduate courses at the University of Illinois. The Air Force Special Weapons Center, and as of 1963 the AFWL, closed the circle of expertise, selecting its engineers for the Structures Division at Kirtland from Dr. Newmark's best students (see Volume I, Part III). The moratorium on nuclear testing of October 1958 dramatically increased military needs to simulate nuclear effects for continued advancements in nuclear weapons systems and hardened construction. Although the brief recurrence of aboveground testing in 1962 again allowed for information gathering during an actual nuclear detonation, the Limited Nuclear Test Ban Treaty of 1963 confirmed the realities and importance of simulated testing.

Eric Wang died in 1960, but the research sponsored through his groups at Wright-Patterson and Kirtland toward shock-tube simulation of nuclear weapons effects lived on as the Air Force Shock Tube Laboratory at Kirtland in late 1961. The University of New Mexico ran the Air Force Shock Tube Laboratory for the Special Weapons Center, subsequently renaming it as the Eric H. Wang Civil Engineering Research Facility (CERF) (Buildings 57001-57012). The University of New Mexico unit managing the CERF evolved into the New Mexico Engineering Research Institute (NMERI). NMERI was the lead group that devised and managed testing using traditional explosives to simulate nuclear detonations. Work at NMERI aided the Air Force in its progress toward the design and

engineering of hardened structures. The Special Weapons Center established the Air Force Shock Tube Laboratory at Kirtland through the physical disassembly and reassembly of the Armour Research Foundation shock tube of 1954 in Gary, Indiana. The middle 1950s shock tube featured four channels of oscillographic equipment to record pressures and durations of shock waves, using barium titanate gages mounted on model items placed in the tube. Test personnel in Gary had employed Primacord detonation at one end of the tube to reproduce shock waves of five to 30 milliseconds duration with peak overpressures up to 30 pounds per square inch (psi). As research went forward at Armour, Wright-Patterson, and the Air Force Special Weapons Center, emphasis shifted from air-blast studies to ones concentrated on underground soils and structures interactions (as appropriate, for example, to the hardening of missile silos). To improve the Armour shock tube as an experimental facility for the study of nuclear weapons effects, the research foundation added a 94-foot extension to the original 150-foot structure and developed another method of Primacord detonation. In this configuration, the shock tube could create peak overpressures of 80 psi for 100 milliseconds duration. The augmented Armour shock tube, in use for the Special Weapons Center but still located in Gary, simulated the effects of a five-kiloton nuclear burst. In achieving an 80-psi shock wave, Armour and Air Force researchers reached the maximum possibilities for operating a shock tube in a densely populated area. Although closing both ends of the shock tube dampened the noise transfer to the surrounding population, no further escalation in psi was reasonable.[69]

After evaluating an alternate choice to move the facility to the Army's Aberdeen Proving Ground in Maryland, the Air Force relocated the Armour six-foot diameter shock tube, along with two smaller associated shock tubes, to an isolated site on Sandia Base. At the time of the relocation, the Armour shock tube was 245-246 feet long, valued at $520,000.[70] The Special Weapons Center intended the New Mexico siting to permit open-ended testing in the tubes. The Air Force wanted to increase psi experiments to significantly improve its capabilities for soils and structures research. The specific purpose of the relocation was to allow the Air Force to gain a better understanding of "ground shock phenomena, the resulting interaction of the shock waves with buried structures and the motions transmitted to their contents."[71] The intent was to duplicate nuclear blast detonations in the low megaton range up to approximately 400 psi.[72] Relocating the Armour shock tubes and their ancillary structures from Gary to Sandia Base was expensive. A major factor in the choice of the New Mexico site was not only the shift of Eric Wang's group from Wright-Patterson to Kirtland, but also ARDC's formal assignment of management responsibility for protective (hardened) construction under Project 1080 to the AFBMD in Los Angeles in mid-January 1960. ARDC funded the disassembly and reassembly of the Armour shock tube on Sandia Base through the Minuteman program within the AFBMD, augmented with monies provided by the DASA. ARDC initially planned to move the shock tube in 1959. The project was delayed slightly and the Air Force extended the Armour Research Foundation's contract to operate the shock tube in Gary until autumn 1960. Through the Albuquerque District of the Army Corps of Engineers, the Special Weapons Center hired an Albuquerque firm, the Bradbury and Stamm Construction Company, to reconstruct the Armour shock tube with planned improvements on Sandia Base.[73]

The Air Force moved two horizontal shock tubes from the Armour facility in Indiana: the six-foot diameter shock tube and a smaller, two-foot diameter shock tube. The six-foot tube consisted of 22 pieces of 72-inch outer-diameter steel pipe that varied in individual length from five to 20 feet. Workmen bolted the flanged ends of sections to one another and mounted the shock tube on a fixed-anchor concrete foundation running east to west at the Sandia Base site. A protective shelter covered all but about 38 feet of the shock tube. A pressure door closed the east end of the tube, while the west end was left open. The two-foot diameter tube was 132.5 feet long, and consisted of six sections of 20-foot length and one of 12.5 feet. The outer diameter of the steel pipe was 24 inches. For the six-foot diameter shock tube, workmen bolted together the flanged ends of each section. No protective

structure sheltered the two-foot shock tube. The smaller tube also featured one closed and one open end. Test personnel continued to use Primacord for detonations, as had been operating procedure in Gary. Primacord was a flexible plastic tubing filled with pentaerythritoltetranitrate (PETN) and wrapped in a cotton cloth. To simulate nuclear blast, personnel wound Primacord on expendable cross wires in the six-foot shock tube and on a steel rack in the two-foot tube. The exploded Primacord created gases that raced from their point of detonation at the closed ends of the tubes to the test sections located near the open ends, magnified in their force by trunnions mounted to the tubes and anchored to the reinforced concrete foundations toward the west ends. (Trunnions traditionally served the same function as lateral mounts for cannons.)[74]

To carry out the soils testing program, the Special Weapons Center designed a bin five feet wide, eight feet long, and 10 feet deep that fit beneath a five- by 10-foot opening on the underside of the six-foot shock tube 179 feet from the west end. For tests, personnel moved the bin into place on tracks and raised it on electrically operated screw jacks. The bin had a capacity of 400 cubic feet.[75]

> By varying the soil properties (relative density, soil type, moisture content, etc.) through a range of reasonable values, it will be possible to study the energy absorption properties of soils and the propagation of high-intensity stress waves. Small structures can be buried within the bin and studies made of the interaction between the soil and the structure in terms of displacement, velocity and acceleration.

As workmen completed facilities for the Air Force Shock Tube Laboratory in mid-May 1961, Air Force Special Weapons Center engineers noted the value of the laboratory for "the design...of our nation's underground missile sites and command and control centers [for Minuteman]."[76] While the shock tube facility was under construction on Sandia Base during 1960-1961, the AFBMD and the Air Force Special Weapons Center jointly worked toward hiring a contractor to operate the facility (formerly the role of the Armour Research Foundation in Gary). The Air Force received seven proposals from prospective contractors for an initial two-year operational contract. The Air Force Special Weapons Center handled evaluation of the proposals. The Special Weapons Center judged those of the University of New Mexico and the Armour Research Foundation as the best of the group and awarded the contract to the University of New Mexico on both technical merit and cost. Signed on 1 May 1961, contract AF 29(601)-4520 outlined a University of New Mexico staff of 37.25 man-years through mid-April 1963, at $434,665. The University of New Mexico appointed Dr. Eugene Zwoyer as head of operations for the Air Force shock tube facility. Dr. Zwoyer, listed both in *American Men in Science* and *Who's Who in Engineering*, had received his master's degree at the Illinois Institute of Technology (IIT) in Chicago and his doctorate degree from the University of Illinois. (Eric Wang's original Special Studies Office at Wright-Patterson had sustained important research contracts with IIT and Dr. Newmark worked at the University of Illinois.) The Special Weapons Center and the University of New Mexico dedicated the rebuilt shock tube on Sandia Base in September 1961. Center personnel commemorated the compound as the Eric H. Wang Shock Tube Facility with a bronze plaque unveiled by Mr. Wang's recent widow. In late May 1965, the AFWL renamed the shock tube complex the Eric H. Wang CERF.[77] By this date, the CERF on Sandia Base included multiple shock tubes, vertical as well as horizontal (Plates 112-113).[78]

The Eric H. Wang CERF sponsored a sophisticated range of testing. Space Systems Division, the follow-on to AFBMD (see Volume II, Chapter 9), provided additional money to the University of New Mexico in June 1961 for Titan program R&D at the CERF. The Air Force Special Weapons Center issued work orders for specific tests at the shock tube complex (as had been the procedure with the Armour Research Foundation). The Special Weapons Center used the initial two-year

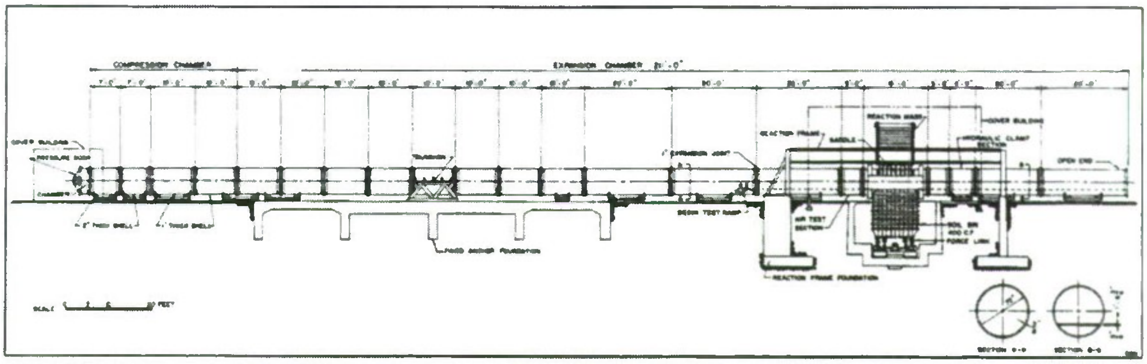

Plate 112: Armour Research Foundation. Six-Foot Shock Tube, 1954. Moved from Gary, Indiana, and reassembled as part of the Civil Engineering Research Facility (CERF) (Buildings 57001-57012), Kirtland Air Force Base, 1961. Courtesy of Ken Bell (formerly, NMERI).

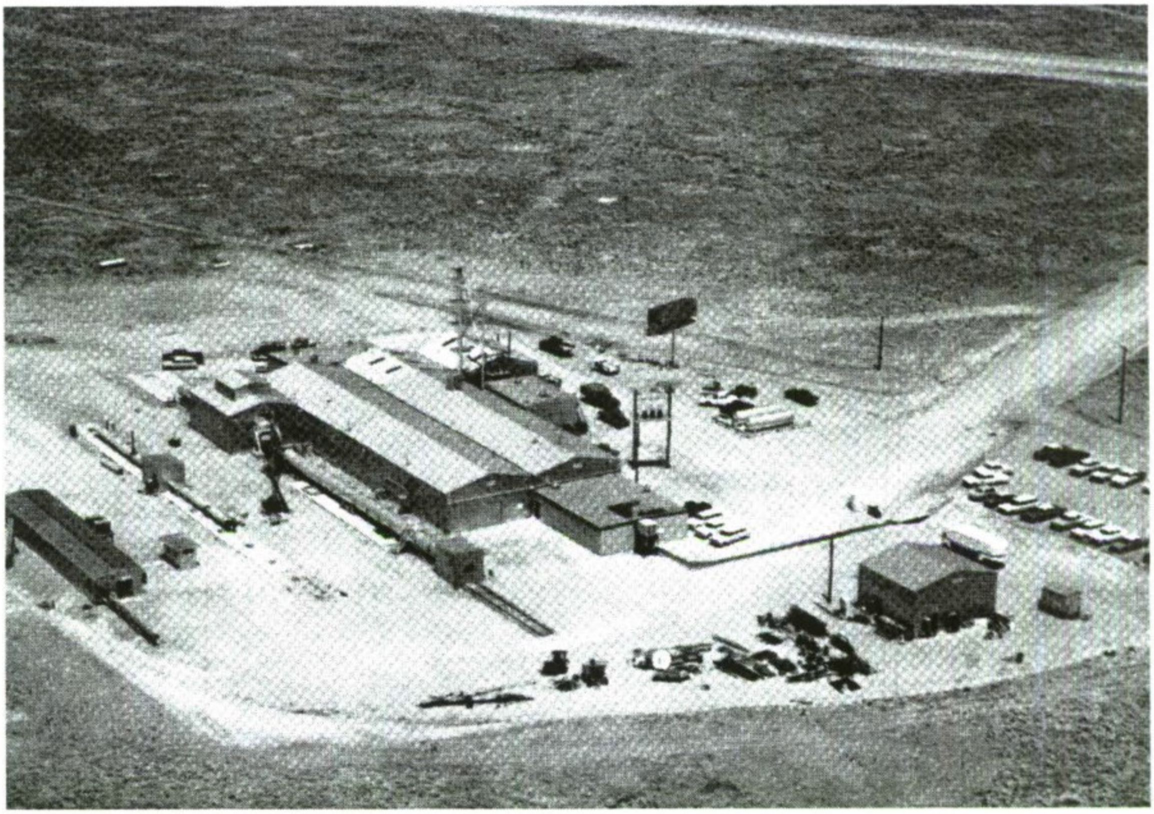

Plate 113: Aerial View of the CERF (Buildings 57001-57012), Kirtland Air Force Base, 1964-1966. In *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1.

contract as a shakedown period for the facility. The University of New Mexico completed 22 work orders for shakedown testing, including:

- general shock tube laboratory operations;
- design studies for a two-foot diameter, 40-foot long vertical shock tube;
- propagation of air pressures;
- development of microwave measuring systems;
- tests of air blast filters (various rock and baffle plate filters to attenuate blast effects);
- multiple air blast and soils interaction studies; and,
- experiments on small buried and bermed structures.

The final shakedown experiment in March 1963 was a second test for space-frame radome models. Work orders varied from as little as $3,000, to one issued at $60,000. The Special Weapons Center issued three work orders (WOs) for modifications to the shock tube facilities, including WO7 (in November 1961, at just under $40,000), WO14 (in April 1962, to modify the two-foot diameter shock tube at $14,000) and WO21 (in August 1962, at just over $3,000).[79]

In 1963, the University of New Mexico added a third shock tube to the complex, taking 40 feet of the original two-foot tube and bolting sections together in a vertical position for pilot soils studies. A frame supported the vertical shock tube at its base, with guy wires attached at the top of the tube and anchored to the concrete foundations of the two horizontal tubes. By mid-year, the University of New Mexico had expanded the Eric H. Wang Shock Tube Facility (CERF) to include seven shock tubes (see Plate 113). Four of the tubes were configured in a horizontal position and three in a vertical position. The four new tubes were:

- a four-inch diameter horizontal tube, expandable to 40 feet and operated using compressed air (with a small soil bin);
- a two-foot diameter vertical tube, 60 feet high, operated using Primacord but with both ends open;
- a 12-inch diameter (inner dimensions) vertical tube, 65 feet high, with an x-ray system; and,
- a 13-inch (also inner dimensions) horizontal tube, 80 feet long, operated using a hydrogen and oxygen mixture.

The 12-inch diameter, 65-foot vertical tube tracked the motions of lead pellets buried in soil to a maximum of 200 psi. NMERI used the two-foot diameter, 60-foot vertical tube primarily for instrumentation testing. Laboratory technicians could achieve maximum overpressures of 250 psi (incident) and 500 psi (reflected) in this tube. Perhaps most remarkable in the middle 1960s, NMERI could create shock waves of 1,000 psi in the 13-inch diameter, 80-foot vertical tube, far exceeding the original 400 psi expectations of the late 1950s for the shock tube complex. Personnel operated the 13-inch vertical tube from a shock-proof control room. When test personnel additionally employed vacuum pumps attached to the expansion test section of the tube, they could simulate overpressures up to 15,000 psi.[80]

The Eric H. Wang CERF added devices, equipment, and laboratories (including x-ray, soil stabilization, dynamic test, and electronics laboratories)[81] through 1967, with experiments at the facility supporting refined concepts of engineering for nuclear weapons effects. Significant projects run at the shock tube complex during 1963-1966 included:

- performance tests on the North American Air Defense Command (NORAD) blast door valve to ascertain appropriate closing times, strength, and general characteristics;
- tests on models of different designs for the air intake units of underground Minuteman systems;

- experiments evaluating the behavior of reentry vehicles (the warheads of intercontinental ballistic missiles [ICBMs]) to shock loadings;
- tests for various designs of a hardened cooling system for Nike-X shelters;
- a feasibility study of a shock isolation system for the Post-Attack Command and Control System (PACCS);
- experiments to better understand the interactive behavior between buried arch-configured structures and the soils in which they were embedded; and,
- soil stabilization studies for key runways at continental United States and international locations.

Other more basic (and simultaneously esoteric) tests featured a series for Army clothing. The Army devised a rain poncho intended to function both as an item to wear and as one that men could adapt to support earthen cover for a foxhole. NMERI ran tests at the CERF on Sandia Base for the Air Force, for contractors working on military projects, and for military service arms across the Department of Defense. NMERI coordinated its work at the CERF with that at other test facilities for some of its studies. A particular challenge in the middle 1960s was the simulation of the blast-induced ground motions created by a large-yield nuclear surface weapon (psi overpressures sustained at 300). For some of these projects, CERF personnel conducted a series of tests on the High Speed Test Track at Holloman.[82]

In May 1963, AFSC redefined the mission of the Air Force Special Weapons Center by making the center primarily a test support installation for missiles development--although nuclear test responsibilities did continue. During the remainder of the 1960s, the Special Weapons Center worked closely with the Air Force Missile Development Center at Holloman until August 1970, when the Special Weapons Center at Kirtland absorbed the Missile Development Center and Holloman ceased to be an installation managed by AFSC. (With this change, a group of German scientists and engineers originally assigned to the Missile Development Center at Holloman during the 1950s through Project Paperclip transferred to Kirtland [see Volume I, Part III].) One of the more important nuclear-test missions of the Special Weapons Center between early 1964 and 1969 was the maintenance of its capabilities to support the National Nuclear Test Readiness Program. The Readiness Division of the Special Weapons Center planned and monitored exercises to maintain readiness to resume nuclear testing prohibited by the Limited Nuclear Test Ban Treaty of 1963. The readiness mission was a costly one, and as nuclear effects simulation expertise advanced, this role of the Special Weapons Center became obsolete. The Special Weapons Center placed its readiness support aircraft, specially fitted B-52s and B-57s, into storage during the early 1970s and AFSC transferred mission personnel to other Air Force units. The missiles-development support mission of the Special Weapons Center also reached a plateau by the middle 1970s. By this date, AFSC channeled advanced missiles work entirely through SAMSO at Los Angeles Air Force Station (see Volume II, Chapter 9). AFSC formally discontinued the Air Force Special Weapons Center at the end of March 1976.[83]

Simultaneously with the 1963 changes for the Special Weapons Center, AFSC created the AFWL as a part of the command's Research and Technology Division. The preexisting Research Division within the Air Force Special Weapons Center (September 1952 – April 1963) was the forerunner for a formal grouping of research laboratories at Kirtland focused on nuclear and advanced weapons development, as well as on the vulnerability and survivability of such weapons. AFSC staffed the AFWL at just over 600 personnel, balanced as about two-thirds military personnel and one-third civilians, and drawn from personnel with previous duties concentrated on nuclear weapons and their effects. The AFWL took over the complex task of monitoring Air Force contracting to the University of New Mexico (NMERI) for the CERF. Before the close of the year, Headquarters Air Force also requested a study to evaluate Air Force civil engineering research. The Structures Division of the

Research Directorate of the Air Force Special Weapons Center had studied the technical problems of protective and hardened construction since Eric Wang's transfer from Wright-Patterson to Kirtland in 1956, and had continued as a unit within the AFWL after May 1963. Following a feasibility study by the AFWL, Headquarters Air Force formalized a sustained assignment of civil engineering research at the laboratory. The AFWL's Structures Branch became the Civil Engineering Branch, with an expanded mission that not only included protective and hardened construction, but also central Air Force management of all civil engineering exploratory and advanced development (see Volume I, Part III).[84]

The separation of the AFWL from the Air Force Special Weapons Center in 1963 immediately encouraged an augmentation of laboratory facilities at Kirtland. Before about 1954, the site that would evolve into today's AFRL compound at the base had been largely vacant land immediately south of several blocks of installation housing at the north end of the north-south runway (see Plate 104). A small grouping of buildings went into place at the location during the middle and late 1950s as the Nuclear Weapons Research Laboratory (Buildings 401, 413, 424, 425, 426, 434, 436, 460, 497, 498, and 499). During the early 1960s and continuing through the decade, AFSC erected a second cluster of laboratories neighboring the first and filling in the site (Buildings 411, 412, 414, 415, 416, 417, 419, and 467) (see Plate 106). The growing laboratory group incorporated several scattered buildings from World War II also on site[85] (also see Volume I, Part III). The formal duties of the AFWL as established in 1963 included:

- definition of nuclear weapons phenomena, radiation hazards, and "environmental interactions related to nuclear detonations;"
- compilation of handbooks for nuclear effects and their countermeasures;
- technical assistance in analyzing Air Force systems vulnerability to nuclear weapons and their effects;
- studies of the technological applications of nuclear power;
- advancement of nuclear weapons delivery and handling techniques / equipment;
- development of nuclear weapons systems training devices;
- nuclear safety analysis;
- specialized studies support for the Advanced Research Projects Agency (ARPA), NASA, the AEC, and other agencies;
- management of the Air Force nuclear weapons effects test program;
- specialized experiments for laboratory and space research;
- maintenance of a technical library capable of providing an AEC – Department of Defense weapons data index for the entire Air Force; and,
- foreign aerospace technology activities.[86]

In July 1963, the Aeronautical Systems Division of Air Force Logistics Command (AFLC) also transferred management control for the Nuclear Aerospace Research Facility (NARF) located at Air Force Plant (AFP) 4 on Carswell Air Force Base in Fort Worth, Texas, to the AFWL. The NARF included a three-megawatt ground test reactor, a 10-megawatt aerospace systems test reactor, a reactivity test assembly structure, a neutron generator, a Cobalt-60 gamma radiation facility, and a flash x-ray unit.[87] The nuclear test area of Convair's AFP 4 had supported a special project in addition to the plant's manufacture of the B-36 (see Volume II, Chapter 15). Titled the Aircraft Nuclear Program, the 1951 project had antecedents back to 1946. The Aircraft Nuclear Program focused on the development of nuclear-powered turbojet engines (with studies contracted to General Electric and Pratt & Whitney) and a nuclear test aircraft (a modified B-36 developed by Convair). The special B-36H, designated the NB (special test bomber) -36H, carried a small, air-cooled nuclear reactor in its aft bomb bay, but flew conventionally. The Air Force constructed a special nuclear test complex at the north end of AFP 4 near the runway, where personnel stored the aircraft reactor when

the NB-36H was not airborne. Flight testing for the NB-36H concluded in 1958, and the Air Force continued using the nuclear reactor ground complex for the Nuclear Aircraft Program until cancellation by President Kennedy in 1961. At a later point in time, the AFWL tore down all buildings at the Carswell site (although AFP 4 remains operational in Fort Worth).[88]

In 1964, the laboratories (primarily within the 400-series cluster) that comprised the AFWL were:

- a space physics laboratory for building rocket and satellite payloads;
- a high-temperature laboratory for conducting "experimental research in the study of thermodynamic and radioactive properties of gases from materials peculiar to nuclear weaponry;"
- a stress wave laboratory "used to study dynamic responses of various materials to stress waves produced by gas driven projectiles and the simulation of certain effects peculiar to high altitude detonations;"
- a transient radiation effects laboratory for researching "responses of electronic circuits in reaction to pulsed neutron and electromagnetic radiation;"
- the six sub-laboratories of the nuclear weapon phenomenology and effects laboratory; and,
- a large animal radiobiology laboratory on Sandia Base, where test personnel irradiated goats, sheep, burros, and dogs to develop a biological dosimeter for military and space use.

The AFWL proposed the addition of a nuclear blast simulator and nuclear integration test facility late in the decade.[89] The effective simulation of blast-induced ground motions was an important priority for the improvement of Minuteman underground launch complexes, and to that end the United States Air Force Scientific Advisory Board asked the AFWL to immediately study confined detonation techniques. The first efforts of the AFWL were those of Project Gas Bag, using "hydrogen / oxygen mixtures confined by a surcharge of water" and later, "high explosives under an earth surcharge." Gas Bag included seven small tests that featured containment cavities 20 by 40 feet in plan. AFWL personnel undertook the initial detonation in March 1964. July tests included two atmospheric events and one employing a containment cavity covered by 7.33 feet of water to achieve the desired pulse duration of ground motion. Detonation effects were similar to those anticipated from the explosion of a 100-kiloton nuclear weapon.[90]

AFWL's work with Gas Bag led to another method for simulating large detonations as of 1965: the High Explosive Simulation Technique (HEST). Project engineers described HEST, which used a woven matrix of Primacord, as producing "predictable peak overpressures, air shock wave front velocities and shape of the pressure time-curve...on an intermediate scale (100 feet by 150 feet in plan)."[91] AFWL improved HEST experiments during the remainder of the 1960s, with intentions to create much higher overpressures during the early 1970s. Selected HEST and HEST-related tests took place near Kirtland, with the earliest full-scale HEST tests conducted at distant sites. AFWL personnel conducted the first full-scale HEST test at the Q-4 (Minuteman) site 35 miles northeast of Cheyenne, Wyoming, in December 1965.[92] Previously, the AFWL and the University of New Mexico (through the CERF laboratories) employed HEST techniques to test an aboveground hardened ultra-high frequency (UHF) antenna (for the launch control centers of Minuteman complexes) on the grounds adjoining the CERF at Sandia Base in July 1965.[93] The AFWL conducted the HEST testing of the Minuteman antenna to support the Ballistic Systems Division in Los Angeles, with a 1,000-psi HEST shot in early February on a full-scale mockup of the UHF antenna. AFWL personnel also had a ½-scale model of the antenna fabricated in Kirtland shops for tests in the 16-foot supersonic wind tunnel at the Arnold Engineering Development Center (see Volume II, Chapter 1), as well as a 1/10-scale model to be tested during late spring 1965 in the 13-inch 1,000-psi vertical shock tube at the CERF.[94]

In March and December 1966, the AFWL ran Project Silt Pile and Project Drill Hole on McCormick Ranch, a test area located to the south of Kirtland and five miles to the southwest of the CERF. The laboratory conducted a second improvement experiment the following June. The AFWL ran HEST II in late July 1966 at the D-1 site, a Minuteman launch control facility 15 miles northwest of Kimball, Nebraska. For HEST III, personnel subjected the M-28 Minuteman site near Valley City, North Dakota, to a simulated nuclear blast in October.[95] By mid-1968, HEST testing near Kirtland (likely on McCormick Ranch) included experiments that buried a scale-model Minuteman launch control center and a large-scale test, Goliath, wherein a sizable underground configuration went in place in 1967.[96] Minuteman hardening against ground motion induced by overpressures continued to be a primary focus of HEST experiments, although as of autumn 1966, personnel were also testing for the effects of electromagnetic pulse (EMP). The AFWL conducted a major EMP test at the Minuteman D-2 site launch facility near Kimball, Nebraska, from August to October 1966.[97] HEST testing continued during the 1970s and 1980s, with variations in the configurations of individual test series and with an emphasis on multiple basing schemes for the MX (missile experiment) Peacekeeper, the follow-on ICBM to Minuteman.[98]

Major facilities construction at Kirtland during the middle and late 1960s continued to augment the laboratories and test complexes of the AFWL. By mid-1966, the AFWL possessed a state-of-the-art physics laboratory to conduct Department of Defense-sponsored research experiments for Transient Radiation Effects on Electronics Systems (TREES) (Building 418). The physics facility featured an ultra-high temperature laboratory, two stress wave laboratories, and a pulse x-ray unit (in planning as of 1962). An arming and fuzing laboratory for the expanding complex was also near completion. To build up radiation testing using large animals, the AFWL contracted for an improved gamma radiation facility (also called the large-animal irradiation facility) in mid-1965. The United States Nuclear Corporation engineered a building below ground near the existing animal farm on Sandia Base (8000 Area). The buried rectangular, reinforced concrete gamma radiation facility included a Cobalt-60 source, placed in a 30- by 50-foot prefabricated metal building which was "set in an 11-foot excavation surrounded by 4 to 10-foot earthen walls." A small prefabricated metal control building housed remote controls and safety equipment.[99]

The AFWL also had the responsibility to directly contract the design of the pulse x-ray equipment needed for the TREES studies. The Test Ban Treaty had stimulated the design of radiography and flash x-ray machines, with DASA intensifying its support for such machines sited at American nuclear effects laboratories. The first flash x-ray machine of the early 1960s, the Febetron, was the product of the Field Emission Corporation (FEMCOR), a start-up company in Oregon founded by former Sandia employees. Only a small handful of companies worked in the field. The other serious competitors included Ion Physics (near Boston), Physics International (near Berkeley, California), and Maxwell Laboratories (San Diego). Ion Physics developed the earliest flash x-ray, the very small FX (Flash X-Ray) 25, during the early 1960s for piece-part level testing. The AFWL at Kirtland purchased the FX 25, the very first Ion Physics flash x-ray machine installed anywhere.[100] During the 1964-1968 period, Ion Physics built a small number of the next flash x-ray machines in the FX series—the FX 45 (twice the size of the FX 25)—for the Army, private military contractors, and military buyers in France and Sweden. The company subsequently built the FX 75 for Boeing in Seattle in 1967 and the final FX machine, the FX 100, for the AFWL. Simultaneously, Physics International designed the alternative to the FX machines, the Pulserad, using a Marx generator rather than the Van de Graaff generator of the FX. The series of Pulserad flash x-ray machines made by Physics International helped to give the AEC and DASA a dual choice for emerging advanced technologies. Physics International's first Pulserad machine was the Pulserad 1150 of the early 1960s. In 1966-1967, Sandia next purchased Hermes I, a Pulserad machine of 10-million volts power for nuclear effects testing. The Air Force contracted with both Ion Physics and Physics International to develop the required machines for nuclear effects simulation facilities at Kirtland.[101] In 1968, the

AFWL installed Ion Physics' FX 100 and Physics International's Pulserad 1590 in one of its laboratories (Building 418). The FX 100 was operational only three months during 1969, while the Pulserad 1590 remained operational until the late 1970s. Both machines produced x-rays for hardness studies related to the Air Force missiles program.[102] By the end of the Cold War, the nuclear effects testing community had commissioned between 30 and 40 flash x-ray simulators, worldwide.[103]

The AFWL continued to sponsor nuclear effects test facilities during the 1970s into the late Cold War. By the late 1960s, the focus expanded to include multiple simulators to address EMP effects caused by nuclear detonations. The brief, intense burst of gamma rays and x-rays created during a nuclear explosion creates EMP, which is a cascading of Compton electrons knocked loose as the rays interact with air molecules. EMP is similar to radio waves in its effect, but millions of times more powerful with a rise time of only a few nanoseconds. EMP also couples with any large or linear metal object such as wire fences, railroad tracks, power lines, and telephone lines. Any electronics systems connected to such wiring, tracks, or other linear metal objects suffer magnified EMP damage, with the objects themselves acting as large antennas for EMP. Although scientists predicted EMP effects even before the first atomic detonation in New Mexico in July 1945, they did not grasp the full implication of EMP problems until a particular nuclear test in 1962. That series of high-altitude detonations near Johnson Island in the Pacific (Fishbowl) included one test, Starfish Prime, that "set off scores of burglar alarms, fouled telephone switching equipment, temporarily disrupted power utilities and radio stations, and shorted out 300 street lights in Hawaii, 800 miles away from the blast."[104] Fishbowl was the first indication of the magnitude of a high-altitude EMP signal.[105] At Kirtland, the AFWL erected five EMP test facilities by 1969-1970.

Construction for EMP testing was underway on base in 1964, beginning with the AFWL / Los Alamos Scientific Laboratory EMP Calibration and Simulation (ALECS) facility designed for testing ICBMs, and the first such simulator built. The ALECS test complex (Building 622), located across the flightline to the southwest of the three double-cantilever hangars, created an electromagnetic environment initially used to assist in the development of electromagnetic sensors for several programs. Dr. Carl E. Baum, of the AFWL, designed ALECS, with the involvement of Edgerton, Germeshausen & Grier (EG&G). (The Los Alamos Scientific Laboratory had hired EG&G to take high-speed photographs of the four shots [atomic bomb detonations] of Operation Greenhouse in 1951 in the Marshall Islands. The EG&G assignment had included photography of the balls of fire and destruction of constructed Air Force and Army buildings, as well as recordation of shock velocities and asymmetries, and cloud tracking.)[106] In 1967, the AFWL converted ALECS to a system test facility for work on the Navy's Polaris and Poseidon sea-launched ballistic missiles (SLBMs), as well as on Minuteman II and III. ALECS featured a closed 100-ohm transmission line strung between 16 inclined wooden poles, coordinated through multiple pulse generators[107] (Plate 114). The energy source for ALECS was aboveground, with an additional underground structure beneath the test pad. The AFWL operated the 100-meter long, 13-meter high ALECS in both pulse and continuous wave modes. ALECS is an example of a guided-wave (bounded-wave / transmission-line) simulator, driven by high voltage generators to propagate an electromagnetic wave through a specific region (working volume) within which personnel place the object in test. Such a test environment typically simulates the free space conditions of a high-altitude nuclear burst, with a vertical electric field and a horizontal magnetic field. The height of ALECS limited the testing of weapons systems in the facility, excluding the vertical positioning of later multistage ICBMs. The fixed nature of the simulator also required that any test object be transportable to Kirtland.[108] A gas gun test unit (no longer present) sat adjacent to ALECS, running east-west.[109]

The four other EMP test complexes of the late 1960s were the Advanced Radiation EMP Simulator (ARES); two Radiating EMP Simulators (RES-I), airborne EMP simulators; an EMP Dipole; and the Horizontally Polarized Simulator (HPS). At this same time, the AFWL also possessed a lightning

simulator, BIG MARX. EG&G and Westinghouse conducted initial feasibility studies for ARES in 1967. DASA selected EG&G to design the final facility in mid-1968. Again, AFWL personnel provided technical guidance in the design of ARES. Continuing the approach to innovation used for the TREES flash x-ray machine, the AFWL contracted for studies from both Ion Physics and Physics International for the high voltage pulsed generator incorporated in ARES. Ion Physics received the final contract to build the pulsed generator in December 1968, at a cost of $1,700,000, with installation of the machine in 1970. ARES (Building 20752) created free field propagated environments, "simulating high altitude nuclear burst conditions, over a volume area large enough to engulf known strategic missiles." ARES included a working volume of about 40 by 33 meters, 40 meters high, covering an overall 37,061 acres (Plate 115).[110] The Air Force erected ARES explicitly to overcome the size and height restrictions present in ALECS. ARES features four laminated wood masts secured through fiberglass down guys. Catenaries supply the transmission line to create a height for the test area working volume of 189 meters. As was true for ALECS, a shielded underground room contained recording equipment.[111]

The AFWL sited the EMP simulators from the 1964-1970 period in two distinct areas at Kirtland, one clustered near ALECS and the other near ARES (across the flightline to the southeast of the ADC alert area). The EMP Dipole was a vertical test structure featuring eight wooden poles and wiring that were positioned with a circular aircraft parking pad. The EMP Dipole exposed full-scale systems to simulated high-altitude nuclear detonation EMP. The AFWL employed it primarily to test instrumentation installed inside aircraft (Plate 116). Dipole simulators use a freely propagating electromagnetic wave, with a test object ideally located at a substantial distance from the wave source. The EMP Dipole was alternately named the Vertically Polarized Dipole I (VPD-I) and the AFWL Characterization Interim Low Level EMP Simulator (ACHILLES) I. The facility accommodated testing of aircraft in a ground-alert mode.[112] The AFWL sited ACHILLES I near ALECS (at Pad 2605, with components removed today). The Air Force replaced the facility with a second, more powerful vertical dipole simulator, VPD-II (alternately named the AFWL Terrestrial High-Altitude EMP Alert Mode Aircraft Simulator [ATHAMAS] II) (Building 20562), near ARES in 1976 (Plate 117).[113] The two airborne EMP generators simulated high-altitude nuclear detonation EMP wave shape, while the HPS was a scale model facility for calibrating instruments and training personnel. Contractors built the airborne generators, RES-I, in two versions—one horizontal antenna and one vertical antenna. The Air Force and the Army used the mobile RES-I during the early 1970s to test large ground-based systems. A helicopter carried RES-I aloft. After difficulties and high costs with the simulators, the AFWL salvaged the antennas and their generators for use in other test equipment.[114] The AFWL contracted for a second "horizontal dipole" simulator (HDP) (Building 20561) during the middle 1970s, collocated near ARES with VDP-II (see Plate 117). Alternately named ATHAMAS I, the HDP was actually a hybrid simulator that was also used for testing aircraft in ground-alert mode.[115]

The AFWL Transmission Line Aircraft Simulator (ATLAS) I was the structure that culminated AFWL's research and design efforts for EMP testing. More commonly known as the trestle (Buildings 20796 and 20797), the structure was designed beginning in the middle 1970s and operational in 1980. ATLAS I was a nearly all-wood laminated structure, with elongated wooden screws and laminated nuts tying together wood trusswork. All EMP simulators contained little or no metal, to assure continuity in the generated EMP field. The challenge in the design of the trestle was in its size. ATLAS I is 400 meters long, 105 meters wide, and 75 meters high. The AFWL used the structure for testing large aircraft. The trestle EMP simulator is the largest of its kind, and among the largest all-wood structures in the world.[116] The ATLAS I trestle actually did have a precursor, an all-wood laminated dirigible hangar designed in 1942 by the Navy's chief engineer at the Bureau of Yards and Docks, Arsham Amirikian. The dirigible hangar was also an engineering feat, built in the continental United States 17 times during the early 1940s. Like ATLAS I, the Amirikian hangars

featured wood screws and nuts, with small steel ring connectors embedded in the laminated boards at the joints. The ring connector increased the strength of the joints by spreading the load more equally over the cross section of the wood, and in fact made the "all-wood" structure possible. The World War II hangar was 1,088 feet long, 297 feet wide, and 178 feet tall—as compared to the 1,312.33-foot length, 344.49 foot width, and 246.06-foot height of the EMP trestle at Kirtland.[117]

Both ALECS and ARES were EMP simulators designed for missiles testing and by 1969, AFWL scientists additionally needed a structure capable of testing large aircraft such as the B-52 (and FB [fighter bomber] -111, EC [electronic cargo] -135, and ultimately, the B-1B). Carl E. Baum postulated that a trestle-like structure could be the basis for a very large, guided-wave simulator. Baum's initial concepts circulated within the AFWL as of spring that year. By mid-1971, the AFWL contracted with the Nuclear Defense Research Corporation of New Mexico to study the ARES, SIEGE, and TORUS EMP simulators, and to provide technical analyses during the design, development, construction, and deployment of ATLAS I. The Simulated EMP Ground Environment (SIEGE) and Transient Omnidirectional Radiating Unidistant and Static (TORUS) simulators were not specific facilities, but rather were types of hybrid simulators conceived in the early 1970s and built thereafter. A SEIGE configuration featured a combination of surface and buried transmission lines, while a TORUS configuration featured an electromagnetic plane wave in a toroid shape high above the earth's surface—such as could be designed through the use of a wood trestle.[118] In March 1972, the AFWL selected three contractors to develop preliminary designs for the trestle simulator, awarding each contractor between $48,000 to $50,000. General Dynamics Corporation, Boeing, and McDonnell Douglas Astronautics Company submitted their proposed designs for the EMP simulator by the end of June. The planned trestle simulator required a Marx generator as its power source, which led to sole-source contracting with Physics International and Maxwell to develop competing designs. The AFWL awarded the two firms about $223,500 each for their efforts. The firms submitted their proposed designs in early 1973. During the years while work went forward, the project encountered some defense funding delays, but the final McDonnell Douglas design under construction at mid-decade.[119] An initial McDonnell Douglas design proposed a double trestle structure, with transmission lines running "vertically" for one trestle and "horizontally" for the other, and both trestles diverging from an aircraft preparation area.[120] The trestle EMP simulator cost about $60 million to build and was expensive to operate (Plates 118-119).

In addition to EMP simulators, the AFWL continued high-explosive testing evolved from the HEST techniques of the middle 1960s, conducting both large-scale detonations for ground shock studies and developing a smaller-scale HEST facility at Kirtland. During 1970-1971, AFWL engineers worked with DNA and SAMSO personnel in planning the events of MIDDLE GUST. The laboratory selected a test site 50 miles east of Pueblo, Colorado, that had geologic characteristics similar to those of the Minuteman missile fields. During MIDDLE GUST I, in mid-September 1971, AFWL personnel produced shock effects at the Colorado test site similar to a nuclear detonation. The blast created a mushroom cloud of dirt and debris 3,000 feet above ground zero, and provided information for the AFWL to develop cratering and ground shock predictions to assist in determining the potential damage to Minuteman emplacements. MIDDLE GUST II followed in mid-December, and resulted in a detonation five times stronger than that of MIDDLE GUST I. For these tests, AFWL built a beehive structure of stacked blocks of trinitrotoluene (TNT). The laboratory team also erected an earth-protected blockhouse away from ground zero. The dirt mushroom cloud of MIDDLE GUST II rose over a mile and created a crater of 50,000 cubic feet.[121] The AFWL ran MIDDLE GUST III, IV, and V during 1972, in continued efforts to assess the in-place hardness of Minuteman. Between the MIDDLE GUST tests of 1971 and those of 1972, AFWL and CERF personnel at Kirtland refined high-explosive techniques through a series of Cylindrical In-Situ Tests (CIST) to develop dynamic soil models. AFWL conducted CISTs in Colorado, Nebraska, Montana, Nevada, and Missouri. Following MIDDLE GUST, laboratory personnel ran MIXED COMPANY, another high-explosive

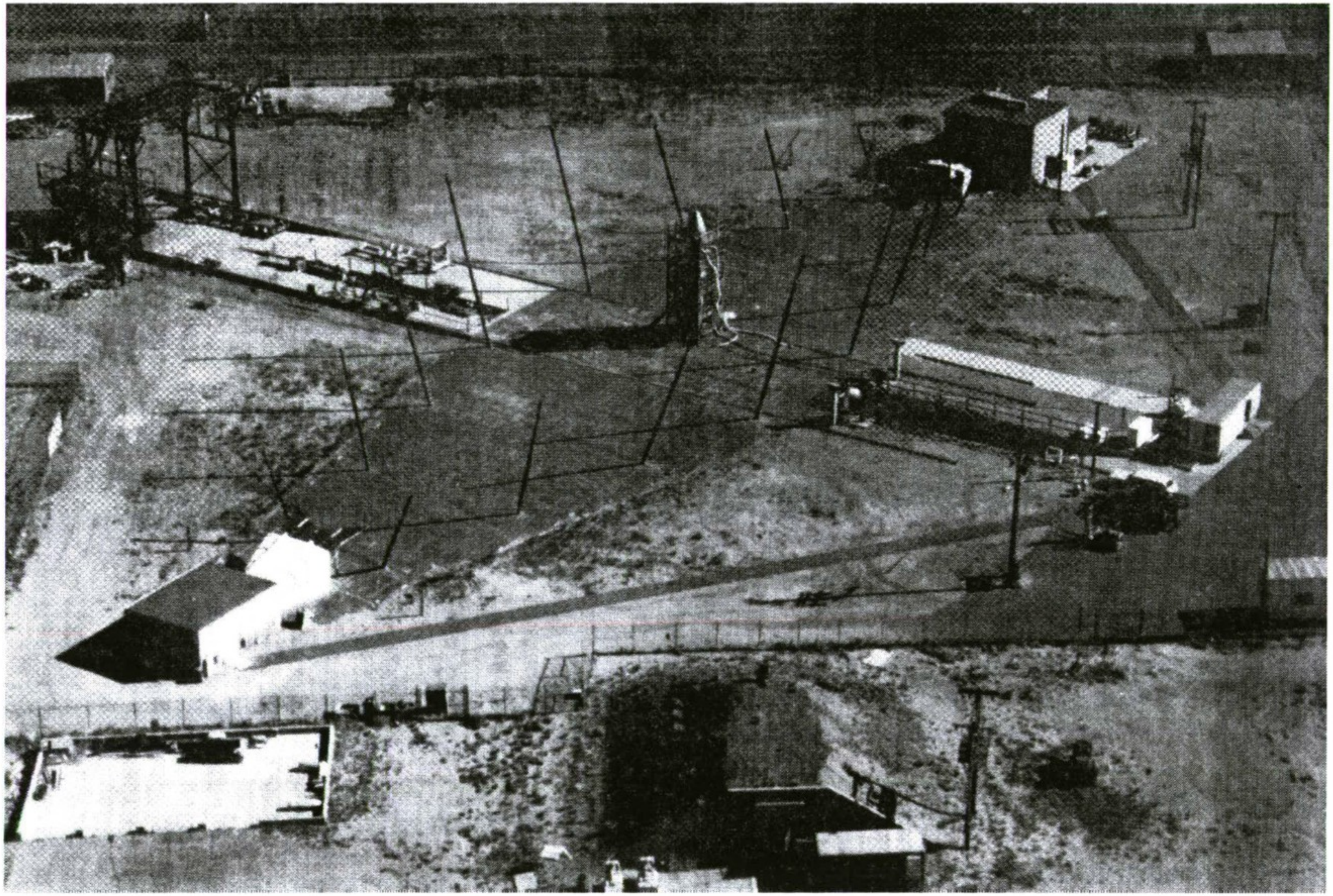

Plate 114: Carl E. Baum and Edgerton, Germeshausen & Grier. The AFWL / Los Alamos Scientific Laboratory EMP Calibration and Simulation (ALECS) facility (Building 622), 1964. In *History of the Air Force Weapons Laboratory 1 January – 31 December 1970*, volume 1.

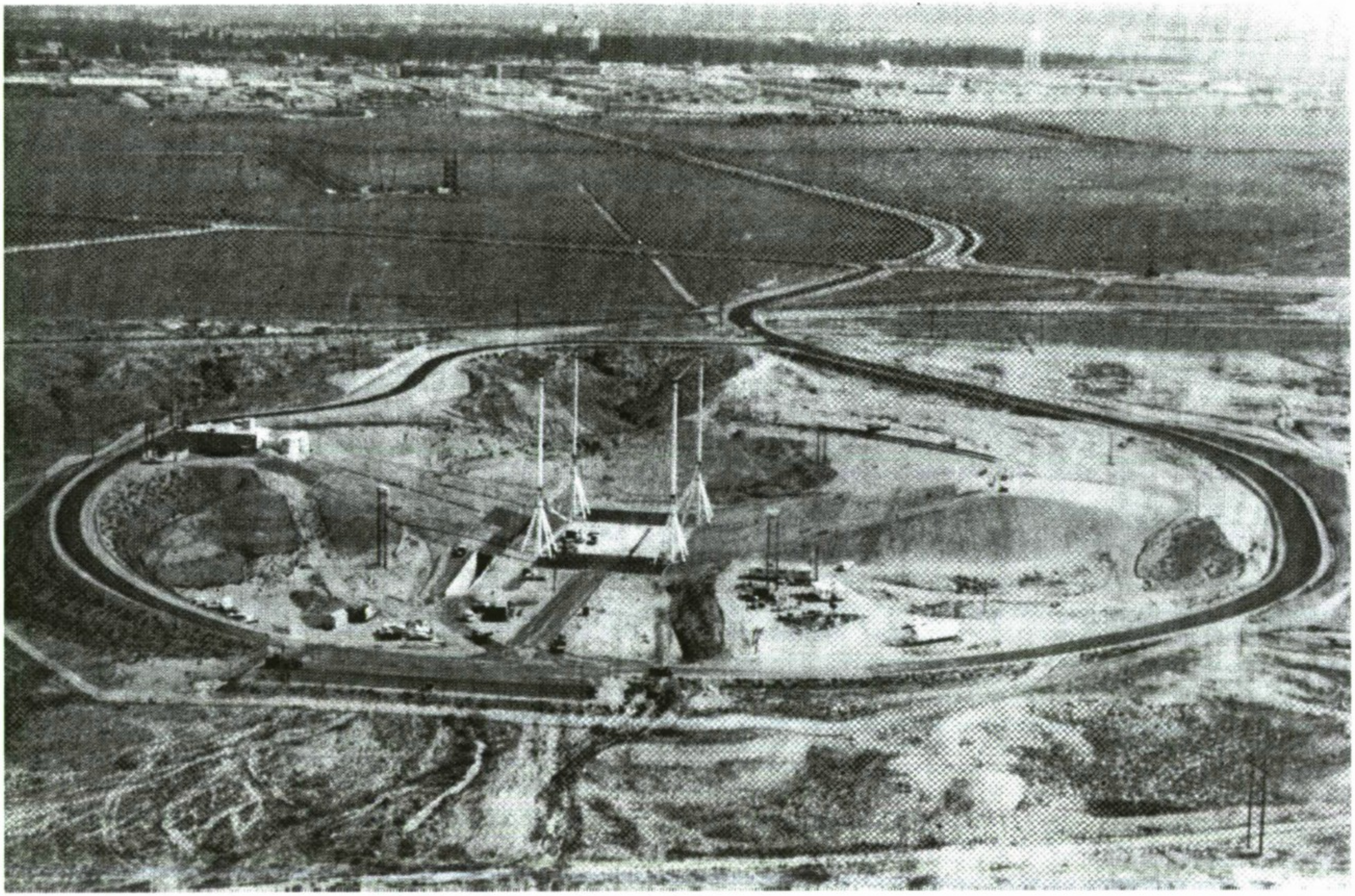

Plate 115: Carl E. Baum and Edgerton, Germeshausen & Grier. Advanced Radiation EMP Simulator (ARES) (Building 20752), Kirtland Air Force Base, 1967-1970. In *History of the Air Force Weapons Laboratory 1 January – 31 December 1970*, volume 1.

Plate 116: Carl E. Baum. Vertically Polarized Dipole I (VPD-I) (ACHILLES I), Kirtland Air Force Base, ca.1968. Formerly located at Pad 2605 near ALECS, today removed. In *History of the Air Force Weapons Laboratory 1 January – 31 December 1970*, volume 1.

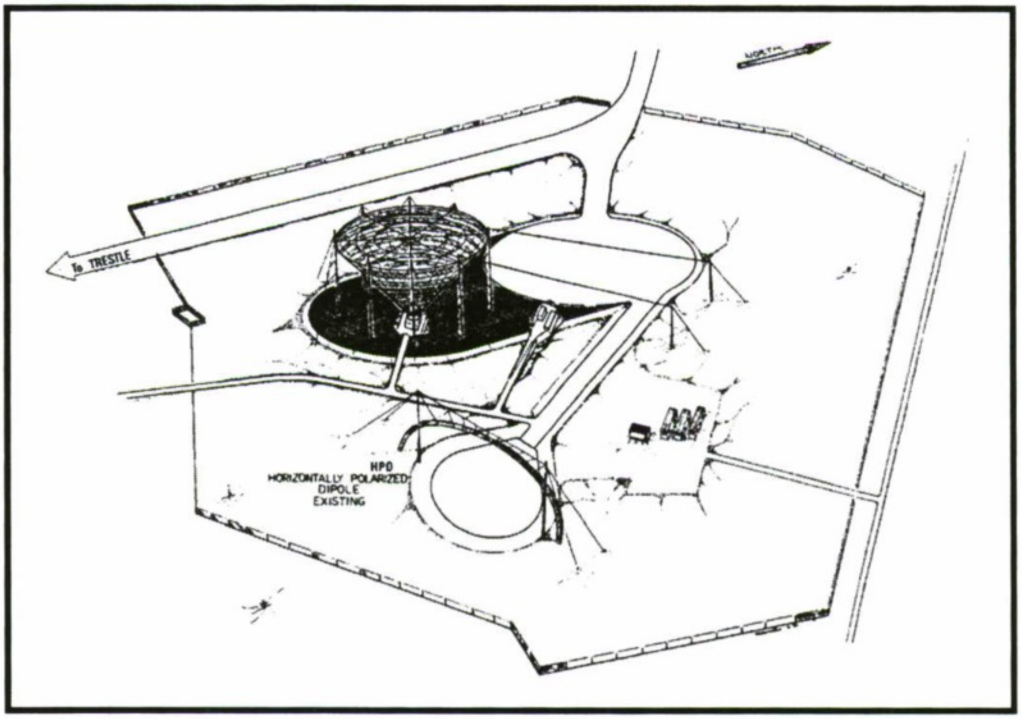

Plate 117: Carl E. Baum and Edgerton, Germeshausen & Grier. Vertically Polarized Dipole II (VPD-II) (ATHAMAS II) (Building 20562), Kirtland Air Force Base, 1976. Shown with the Horizontal Dipole (HDP) (ATHAMAS I) (Building 20561), 1975. Courtesy of Civil Engineering, Kirtland Air Force Base.

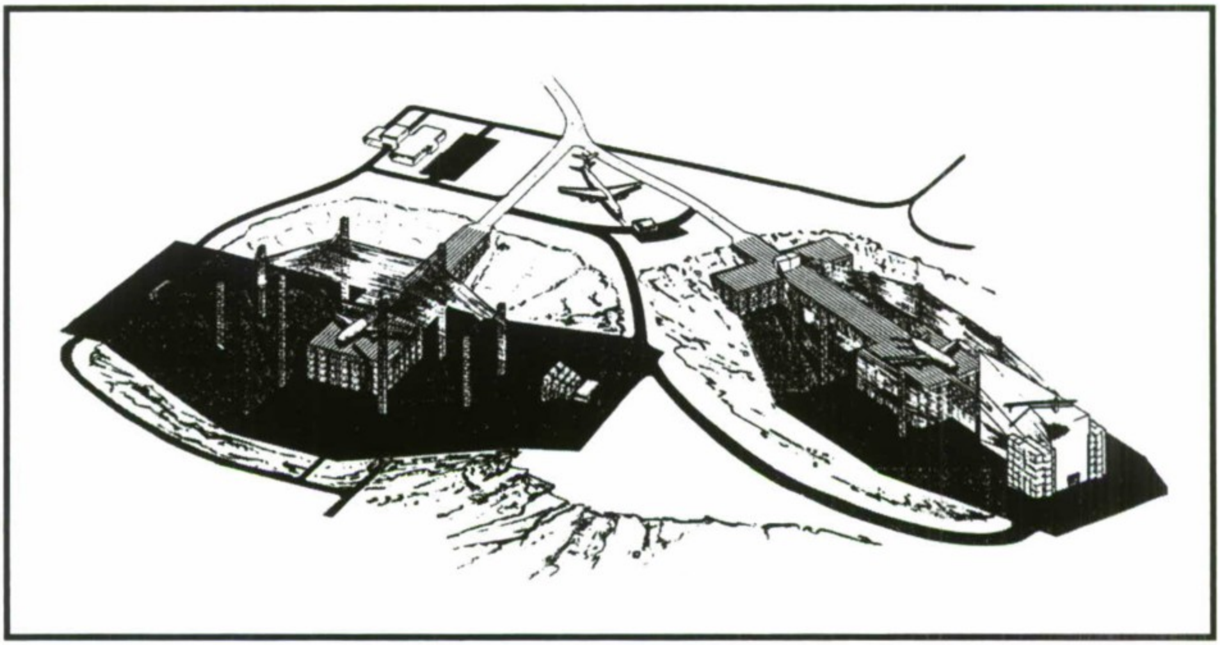

Plate 118: McDonnell Douglas. Concept drawings for a double-trestle EMP test facility at Kirtland Air Force Base (unbuilt), 1973. Courtesy of Civil Engineering, Kirtland Air Force Base.

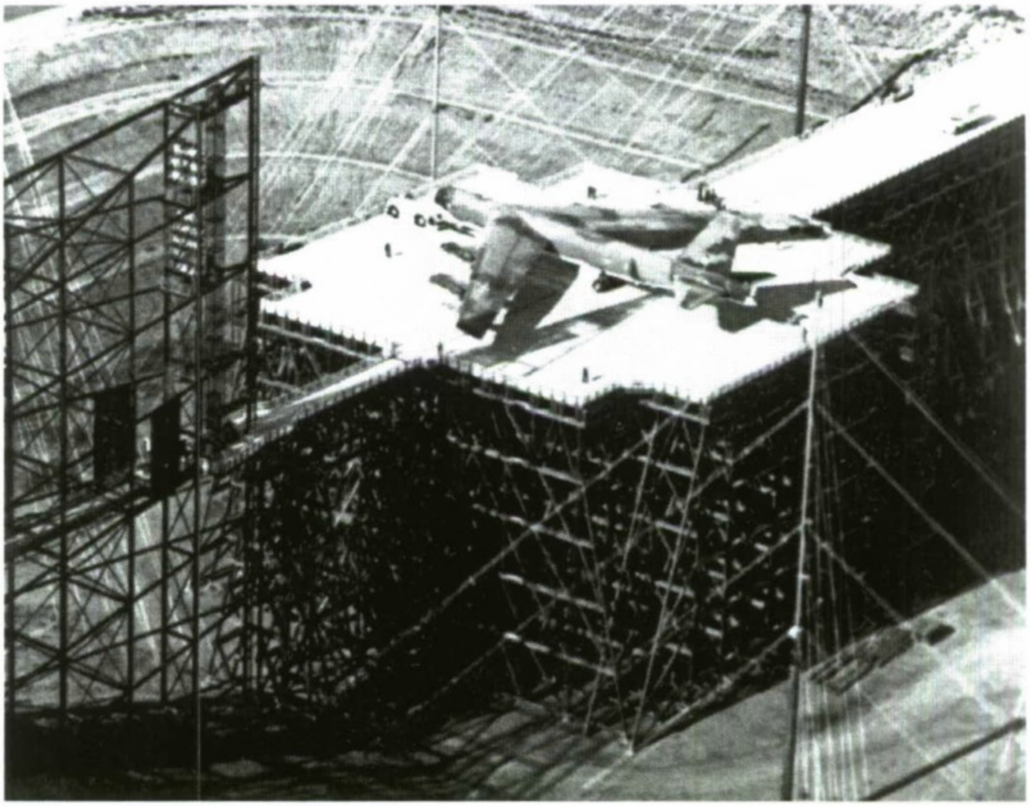

Plate 119: Carl E. Baum and McDonnell Douglas. AFWL Transmission Line Aircraft Simulator (ATLAS) I, the "Trestle" (Buildings 20796 and 20797), Kirtland Air Force Base, 1975-1977. With B-52 in test. Courtesy of the AFRL History Office.

series, sited near Grand Junction, Colorado, as well as the Pacific Cratering Experiment (PACE) on Eniwetok in the Marshall Islands—both also during 1972. MIXED COMPANY focused on experiments for the hardened aircraft shelter program (see below).[122]

HEST detonations simulating the airblast from a nuclear explosion over a large geographic area were expensive and destroyed the test facilities during each event. These circumstances led the AFWL to develop a small-scale, reusable HEST structure named GRABS (Giant Reusable Airblast Simulator) in 1971. The AFWL located GRABS, a reinforced concrete cylinder lined with a steel plate built into rock, to the south / southwest of Manzano Base just north of the Sandia border with the Isleta Indian Reservation. GRABS allowed testing of surface-flush and buried units in the cylinder, with experimentation using different soils and depths to bedrock. Again, as was the case of many testing efforts of the AFWL during these years, GRABS simulation was explicitly oriented toward the assessment of the hardness of Minuteman facilities. As a predesign study for GRABS, the AFWL ran three downscaled tests, called Mini-GRABS, using existing concrete test silos sited in the ROCKTEST I and II facilities near Estancia, New Mexico. CERF personnel worked closely with the AFWL on these initial tests. Mini-GRABS established the preference for Primacord, rather than a single-sheet explosive, as the method of detonation. CERF designed GRABS using a computer program, creating an 18-foot diameter silo, 48 feet deep, with a ¼-inch steel liner surrounded by a two-foot-thick reinforced concrete wall—the entire structure built into an existing massive limestone formation on the south edge of Sandia Base (Plate 120).

The DNA funded GRABS at $74,000. The AFWL planned to reuse the test facility for 13 different simulated nuclear detonations. Following the completion of construction in April 1971, laboratory personnel ran the first two GRABS detonation tests in July and September. The AFWL adjusted the soil test bed inside the silo for each test. SAMSO at Los Angeles Air Force Base monitored 98 measuring gages at varying depths in the test structure from an instrumentation van 500 feet from the test site. The AFWL developed a second test scenario derived from HEST to simulate horizontal motions caused by a shock wave induced directly in the ground. The laboratory called the new methodology the direct-induced high explosive simulation technique (DIHEST). Early DIHEST testing supported the Air Force Hard Rock Silo Program. DIHEST experimentation for the program uniformly occurred in rock settings. Shifting DIHEST to a soils environment, referenced as the DIHEST Improvement Program (DIP), the AFWL built a test facility eight miles south of Kirtland on the McCormack Range test site. Test personnel configured the DIP test facility as a 15-foot diameter hole, 46 feet depth, with a 10-foot diameter, 10 foot, 4 inch open-ended steel cylinder placed in the bottom of the cavity and filled with 40 tons of slurry explosive equivalent to 50 tons of TNT (see Plate 120). For DIHEST tests, an instrumentation van sat 2,000 feet from the buried explosive charge.[123]

Supplementing the nuclear effects testing managed at Kirtland from the early 1960s forward, the Civil Engineering Branch of the AFWL also handled a sophisticated range of challenges for the wider Air Force related to hardened structures and to pressing traditional problem sets. The Civil Engineering Branch of the AFWL became involved in the hardened aircraft shelter program in 1963. After erection of the first test shelter at Eglin (see Volume II, Chapter 4), AFSC assigned the AFWL testing missions to determine the protective strength of the prototype structure. AFWL's role focused on determining an optimum design for shelter doors able to withstand multiple types of munitions damage. The hardened aircraft shelter program advanced as one for non-nuclear shelters needed in Southeast Asia and as one suited for air bases in selected North Atlantic Treaty Organization (NATO) countries. The Vietnam War also created the need for aircraft revetments. The AFWL filled a critical role in the design, development, test, and evaluation of two generations of structures erected during the middle-to-late 1960s. The aircraft shelter program included 10 phases of Concrete Sky for Vietnam and Southeast Asia from 1966 into the early 1970s, as well as Theater Air Base

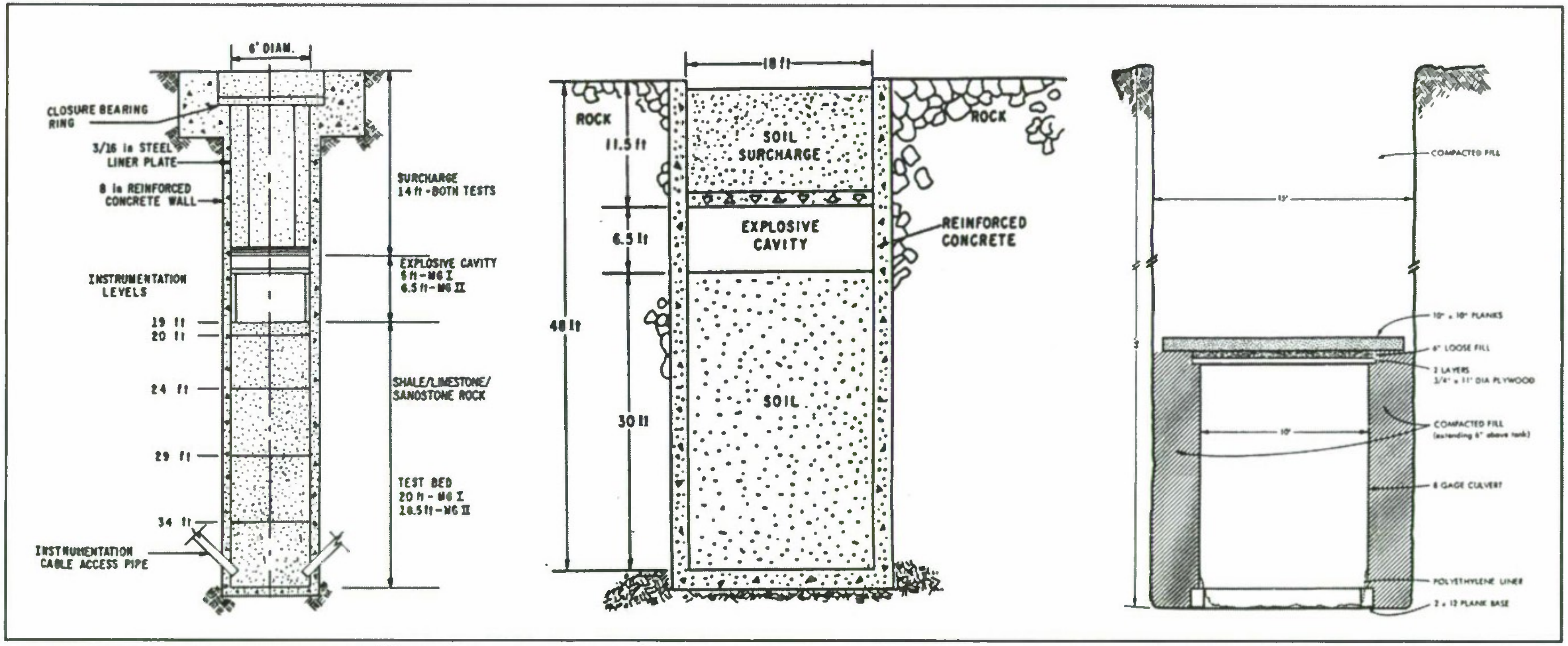

Plate 120: Giant Reusable Airblast Simulator (GRABS) Tests, 1971. Left to right: Mini-GRABS, ROCKTEST I and II, near Estancia, New Mexico; GRABS, south / southwest of the Manzano Area, Kirtland Air Force Base; and, the Direct-Induced High Explosive Simulation Technique Program (DIP) test cylinder, McCormack Range, south of Kirtland Air Force Base near the northern border of the Isleta Indian Reservation. In *History of the Air Force Weapons Laboratory 1 January – 31 December 1971.*

Vulnerability (TAB VEE) for worldwide deployment. AFWL's role remained concentrated on munitions tests, including evaluations of overflight damage potential as well as the shelter's capacity to contain internal explosions (from sabotage). In 1966, through Project 1597, the AFWL canvassed private industry to find an existing structure that laboratory personnel could convert into a liner for the Concrete Sky shelter. The AFWL chose a double-corrugated steel arch structure manufactured by the Wonder Trussless Building Company of Chicago. Known as the "Wonder Building," the inner liner for the protective aircraft shelter dated to 1950. The Wonder Building was a patented, self-supporting steel arch structure. Wonder Buildings became the replacement choice for an earlier shelter liner developed at Eglin in 1962, with yet a third liner tried during the earliest Concrete Sky experiments of 1966-1968. The American military employed prefabricated Wonder Buildings for permanent stations in Antarctica as of the early 1950s and for a variety of hardened underground structures. The distinctive structures also became the basis for standard fallout and bomb shelters.[124]

The AFWL's participation in the hardened aircraft shelter program continued from 1963 until 1992, when the Air Force discontinued hardening improvements for the shelters following the end of the Cold War. Testing for Concrete Sky and TAB VEE occurred on the ranges at Eglin, at the Utah Test and Training Range (UTTR) associated with Hill Air Force Base (see Volume II, Chapters 4 and 6), and in Europe and Vietnam. Tests in immediate proximity to Kirtland, in which the AFWL participated, ran in Coyote Canyon on Sandia's land (where a standing Concrete IX shelter from 1971 remained in 2000), as well as multiple other sites in southern New Mexico (Plate 121). The AFWL also tested Concrete Sky and TAB VEE shelters in the MIXED COMPANY high-explosive detonations near Grand Junction, Colorado during 1972.[125] The multigenerational aircraft shelter programs included contracted efforts by Holmes & Narver of Los Angeles in the late 1960s and by Leo A. Daly in the middle 1970s. Holmes & Narver had been involved in hardened construction

Plate 121: Concrete Sky IX Test Structure, Coyote Canyon, Kirtland Air Force Base, 1971. Photograph of March 2000. K.J. Weitze for EDAW, Inc.

since test site design for Operation Greenhouse in the Marshall Islands in 1951, while Leo A. Daly was the firm SAC commissioned to design its alert crew quarters of the late 1950s and its first- and second-generation underground command posts at Offutt Air Force Base in Nebraska. NMERI worked with the AFWL in conducting munitions tests for the shelters in the late Concrete Sky phases. The final effort for the shelter program was Distant Runner in tests run during the middle 1980s at the UTTR (see volume II, Chapter 6). Involved from the late 1950s through the early 1990s was Weidlinger Associates, Inc., the New York firm of Paul Weidlinger. Weidlinger was a Hungarian engineer who, like Nathan Newmark, was one of the major experts on hardening throughout the Cold War period (see Volume I, Part III).[126]

The Civil Engineering Branch of the AFWL also conducted many traditional studies to meet Air Force challenges during the 1964-1972 period. One excellent example was airfield and runway pavement studies. From at least the middle 1960s forward, the Civil Engineering Branch worked on improving pavement for rapid runway repair of bomb-damaged facilities in Southeast Asia. Efforts were in tandem with those of the Aero Propulsion Laboratory and the Civil Engineering Center at Wright-Patterson. The Civil Engineering Branch conducted most of its physical testing on the ranges at Eglin.[127] Pavement studies through the Civil Engineering Branch of the AFWL were intense a second time during the late 1960s and early 1970s. The AFWL tested and evaluated different types of pavement over 1968-1971 for a jointly sponsored effort by the Army, Air Force, and Federal Aviation Administration (FAA). Multiple universities were also involved in subcontracted roles through the laboratory. Just as had been the case for the heavy bombers of World War II, and then for the B-36 at the outset of the Cold War, an oversized aircraft in development forced a reevaluation of the design and engineering of runways and parking aprons. The C (cargo) -5A transport aircraft, built by Lockheed, weighed 750,000 pounds—more than twice as much as any other plane then in service. (The B-36 series had weighed in at between 260,000 to 320,000 pounds, unloaded.) While the C-5A was a multiple-wheeled aircraft, its extreme tonnage was a serious issue for both flexible and rigid pavements. Efforts of the AFWL generated a four-volume technical report. The Army's Waterways Experiment Station in Vicksburg, Mississippi, and its Construction Engineering Research Laboratories in Champaign, Illinois, participated in the project. The University of New Mexico's CERF also conducted studies. AFWL testing occurred at multiple locations, including ones at Eglin and Hurlburt in Florida, Dyess Air Force Base in Texas (to evaluate the C-5A's ability to land on specially developed aluminum mat runways), and Altus Air Force Base in Oklahoma (to test erosion problems created by the C-5A during takeoff). The AFWL coordinated their pavement studies with flight testing running concurrently at Edwards Air Force Base in California, including the development of a prototype hangar for the C-5A (see Volume II, Chapter 3). In California, one C-5A test for the AFWL used an unsurfaced soil runway at Harper Lake. Similar to studies of World War II, the AFWL looked to the innovations of leading state highway departments.[128] In June 1972, Headquarters Air Force reconfigured the Civil Engineering Branch of the AFWL as the Air Force Civil Engineering Center (today, the Air Force Civil Engineer Support Agency) and moved it to Tyndall Air Force Base in Florida (see Volume I, Part III).

During the 1970s, a number of sequential changes occurred at Kirtland that affected its organization and management. The changes were partially an outcome of the continued shifting toward nuclear effects testing and the arrival of ever-more sophisticated weapons research. They were also partially due to larger Air Force command reorganization as the Vietnam War wound down and ended. In 1970, the Air Force Missile Development Center at Holloman merged with the Air Force Special Weapons Center. The next year, Kirtland acquired the full acreage of neighboring Sandia Base. The Sandia National Laboratories, run by the Department of Energy, became a tenant on the installation. Manzano Base became the Manzano Area of Kirtland. When the general civil engineering function within the AFWL moved to Tyndall in mid-1972, elements of the Concrete Sky aircraft shelter

program shifted there as well. In January 1974, the Air Force activated the Air Force Test and Evaluation Center (as of 1983, the Air Force Operational Test and Evaluation Center) at Kirtland, in response to pressure to prioritize the operational test and evaluation functions of the armed services. The Air Force Operational Test and Evaluation Center became a prominent tenant mission on base.[129] In 1976, AFSC abolished the Air Force Special Weapons Center and the next year MAC became the base host command for the remainder of the Cold War period. AFSC tiered the AFWL under SAMSO at Los Angeles Air Force Station (an installation that evolved into Los Angeles Air Force Base). Between the late 1970s and the end of the Cold War, AFSC repositioned the AFWL within the Air Force Space Technology Center, and subsequently within the Phillips Laboratory. The command discontinued the AFWL in 1990. Its laboratories are part of the AFRL within Air Force Materiel Command in 2003 (see Volume I, Part II). Missions at Kirtland continued to be firmly tied to the development of late Cold War missiles (ICBMs and cruise missiles), nuclear weapons effects studies, and research toward high-energy laser systems.

Weapons systems testing at Kirtland, and in the associated facilities erected on neighboring Sandia Base, was necessarily very complex throughout the Cold War and is only highlighted in discussions above. One final arena of R&D in the 1970s and 1980s was that of high-energy laser, particle-beam, and advanced weapons conceptual studies. Beginning in 1972, and paralleling direction for sophisticated nuclear effects testing, AFSC formally assigned the AFWL responsibilities for the Air Force's portion of the Department of Defense's high-energy laser program. One example of this critical program included the AFWL's Advanced Radiation Technology Office and its work on gas dynamic, electric discharge, and chemical lasers. The office included a test range for laser devices that opened in 1970 as the Sandia Optical Range (the Directed Energy Experimental Range as of 1984). The very first American high-energy laser, the Air Force Laser I, operated on the Sandia Optical Range in 1971.[130] A key component of the laser studies at Kirtland during the final decades of the Cold War was the Airborne Laser Laboratory (ALL). The ALL was a modified NKC (special-test tanker) -135 aircraft, "equipped with a carbon dioxide laser and an airborne pointing and tracking system."

The ALL facilities occupied sites on both sides of the Kirtland flightline between the early 1970s and the middle 1980s (see Plate 106). The KC-135 area on the north side of the flightline to the west of the ADC FIS alert cluster used three circular hot-cargo pads that had been in place at the location by 1966. The NKC-135 was sometimes parked on one of the pads. (The free world's only aerial laser platform, the ALL carried highly toxic and explosive laser fuels.) Other KC-135s occupied the pads as part of the Advanced Airborne Demonstrator Project in the middle 1980s. These KC-135s were modified through the addition of upper capsules of electronics equipment (and may have carried an "EC" [electronics-modified cargo] designation) (Plate 122). On the south side of the flightline, a second KC-135 area existed. In 1973, major design was underway for the Armament Research Facility / Advanced Radiation Technology (ART) to the northwest of the ARES and trestle EMP test facilities. (Some work had occurred at the site by 1963.) The ART included the ALL assembly hangar (Building 760) designed by the New York engineering firm Burns & Roe of New York—the firm hired to design and engineer the SAGE Combat and Direction Centers for ADC (see Volume I, Part IV), and one best known for its design of nuclear power plants. The ALL hangar featured a control room and specialized test cells. An assembly and maintenance building were also on site, as well as instrument and avionics laboratories.[131] The Air Force reused Building 760 for the Advanced Airborne Demonstrator Project, adapting a fourth hot-cargo pad (Pad 2634) that had previously been used for the NKC-135 mission. The ALL garnered national military attention during the early 1980s, when the NKC-135 destroyed five Sidewinder missiles in mid-air over the Naval Weapons Center Range at China Lake, California, to the north of Edwards. In sequential aerial tests near the Navy's Point Mugu facility south of Santa Barbara, an ALL destroyed a subsonic Navy drone flying a few hundred feet above the Pacific Ocean.[132] In 1988, the AFWL retired the ALL to the Air Force

Plate 122: Advanced Airborne Demonstrator Project, Hot Cargo Area, Kirtland Air Force Base, ca.1985-1988. Courtesy of the 377th Air Base Wing History Office, Kirtland Air Force Base.

Museum at Wright-Patterson.[133] Immediately before this date, the Advanced Airborne Demonstrator Project assumed responsibility of the ALL facilities at Kirtland.[134]

During the 1980s, other AFWL laser and advanced weapons work included efforts for the Improved High-Altitude Radiation Detection System (IHARDS) for Space Command (later, Air Force Space Command [AFSPC]) and SAC; the Ground Wave Emergency Network (GWEN) for SAC; and, the EMP Test Aircraft (EMPTAC). Laser research featured scalable supersonic chemical oxygen-iodine lasers (COIL); phased array telescopes for transmitting high-energy laser beams; an exploding wire-pumped iodine laser; an optically-pumped iodine monofluoride laser; and, a large-scale cylindrical deuterium fluoride laser. At the end of the Cold War, laboratory personnel selected the COIL, initially developed in 1977, for installation on a second-generation airborne laser aircraft. The AFWL also participated in research toward the SDI after 1983. SDI projects accounted for 60 percent of the laboratory's budget by 1987. Other examples of major test facilities at Kirtland bracketing the 1970-1991 period included the Starfire Optical Range (Building 66001) for laser research into propagation problems caused by atmospheric turbulence (1970) and SHIVA STAR (first named the SHIVA I), a cylindrically configured power source producing intense x-rays through plasma implosion for weapons effects testing (1971).[135] At the end of the Cold War, the AFWL sponsored the High Energy Research and Technology Facility (HERTF) for testing advanced weapons systems

involving high-power microwaves, high-energy pulsed power, and high-energy plasma under conditions of intense high-explosive blast and radiation (1991).[136]

Key Associated Architects and Engineers

Architects and engineers of national significance responsible for structures' design at Kirtland during the Cold War include a large and prominent group. Most of these firms are discussed in Volume I or in other chapters of Volume II, as noted:

- Black & Veatch, of Kansas City (Volume II, Chapter 4);
- Burns & Roe, New York (Volume II, Chapter 1);
- Holabird, Root & Burgee, of Chicago (Volume I, Parts III and IV);
- Kuljian Corporation, of Philadelphia (Volume II, Chapter 3);
- Mills & Petticord, of Washington, D.C.(Volume I, Part III);
- Strobel & Salzman, of New York (Volume II, Chapter 5); and,
- Weiskopf & Pickworth, of New York.

In addition, several engineers of national and international note worked on complex problems of design for nuclear hardening at, or in association with, the AFWL (see Volume I, Part III), including:

- Nathan M. Newmark;
- Eric Wang; and,
- Paul Weidlinger.

Weiskopf & Pickworth

Weiskopf & Pickworth is a structural engineering firm with a prestigious practice that continues into the present. The firm was a multigenerational one known for its collaborative work with major architects. Walter H. Weiskopf (1899-1958) graduated with a civil engineering degree from Rensselaer Polytechnic Institute in 1920. During World War II, he served as chief engineer for the New York District of the United States Army Corps of Engineers and subsequently worked for United States Steel and Carnegie Steel for nine years before joining his father's firm, Weiskopf & Pickworth. During 1954-1955, Weiskopf & Pickworth designed a reinforced concrete checkout and assembly structure for the FFAR. Significant civilian buildings for which the firm provided consulting engineering design services in the 1950s included Lever House (with architects Skidmore, Owings & Merrill, 1951-1952), Manufacturers Trust Company Bank, the Union Carbide Building, and Chase Manhattan Bank, in New York; the United States Senate Building in Washington, D.C.; and, the Ford Motor Company Office in Dearborn, Michigan. Earlier important Weiskopf & Pickworth buildings were the Equitable Trust Company Building, the Hayden Planetarium (with architects Trowbridge & Livingston, 1934-1935), and New York Daily News Building (with architects Raymond Hood and John Mead Howells, 1928-1930) in New York; the Mitsui Bank in Tokyo; and, the Gulf Oil Company Building (with architects Trowbridge & Livingston, 1931-1932) in Pittsburgh.[137] During the early 1990s, Weiskopf & Pickworth was responsible for the engineering specifications for several prominent skyscrapers, including I.M. Pei's Raffles City, a 72-story hotel in Singapore that is among the world's tallest buildings.[138]

---

[1] The reader can trace the broad patterns of lineage for the installation in the Kirtland Air Force Base chapter in Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). The Kirtland chapter includes the sequence of installation names through 1982; dates of establishment, construction, and occupancy; base

operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base.

[2] "Q" is a designation derived from the "Q clearance," a security clearance category within the AEC (today, the Department of Energy). A Q clearance is approximately equivalent to the Top Secret clearance within the Air Force.

[3] Don E. Alberts and Allan E. Putnam, *A History of Kirtland Air Force Base 1928 – 1982* (Kirtland Air Force Base: Air Force Test and Evaluation Center and the 1606th Air Base Wing, June 1982), 1-26.

[4] *Ibid*, 26-41. The name of the installation derives from the nearby Sandia Mountains. *Sandia* is the Spanish term for watermelon.

[5] Necah Stewart Furman, *Sandia National Laboratories: The Postwar Decade* (Albuquerque: University of New Mexico, 1990), 92-98.

[6] Alberts and Putnam, *A History of Kirtland Air Force Base*, 1982, 46-54.

[7] Furman, *Sandia National Laboratories*, 1990, 125-138.

[8] Daniel R. Bilderback and Michael S. Binder, *Early DoD-Sited Nuclear Warhead Infrastructure* (University of South Carolina Legacy Project: May 1999), 34. Bilderback and Binder mis-state the number of igloos in the 6000 Area as 12; the correct number is 10. The architectural-engineering firm for these igloos is very likely Black & Veatch.

[9] Furman, *Sandia National Laboratories*, 1990, 125.

[10] *Ibid*, 216-217.

[11] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 97-107.

[12] Black & Veatch, consulting engineers, with W.C. Kruger and Associates, "Troop and Administration Facilities Sandia Base. Post Administration Building," 29 January 1947. For an overview history of Sandia, see also: Leland Johnson, *Sandia National Laboratories: A History of Exceptional Service in the National Interest* (Albuquerque: Sandia National Laboratories, 1997).

[13] The Air Force units in charge of NSS and OSS areas, as well as later nuclear weapons storage facilities of other types, were typically called Aviation Depot Squadrons. As of 1950, Kirtland supported another specific military unit called an Aviation Field Depot Squadron. These numbered units were of short duration, usually only six to eight months, and were "training" units activated before the Air Force redesignated the squadrons at its OSS areas. The Aviation Field Depot Squadrons trained at Kirtland sequentially between November 1950 and November 1953, and included Aviation Field Depot Squadrons 1-19 (although possibly with some gaps in this numbering). The total program of NSS and OSS areas is not easy to verify or research, and remains a topic requiring further study—particularly with relation to Kirtland's role during the earliest years of construction and the readying of the special storage areas for takeover by SAC. See Mueller, *Active Air Force Bases*, 1989, 292. Unit histories for the Aviation Field Depot Squadrons exist at the Air Force Historical Research Agency at Maxwell Air Force Base.

[14] A cultural resources inventory of Manzano Base exists in draft as of mid-July 1998. The document is tentatively classified as For Official Use Only (FOUO), although is released in semipublic circulation. Document reference is Bruce T. Verhaaren, *Cold War Resources*, part II of *A Cultural Resources Inventory of the Manzano Storage Area*, Draft (Lakewood, Colorado: Argonne National Laboratory, for Air Force Materiel Command, 22 July 1998). The document contains errors and should be approached cautiously. Dr. Verhaaren omits any discussion of Black & Veatch, also offering very few contextual details for the overall nuclear weapons storage program of 1946-1959.

[15] Many problems exist with the current state of research for NSS and OSS areas. Verhaaren's *Cold War Resources* contains some confused discussion for Manzano Base. Another study, also missing many pieces of the story and containing errors, is that of Bilderback and Binder, *Early DoD-Sited Nuclear Warhead Infrastructure*, May 1999. The author is currently working on a more detailed analysis of the NSS and OSS program as part of a study for Headquarters Air Combat Command.

[16] Alberts and Putnam, *A History of Kirtland Air Force Base*, 1982, 69.

[17] Air Force Special Weapons Command, *History Special Weapons Command 1 December 1949 – 30 June 1950*, 6-7.

[18] The building number for this structure remains undetermined. It is also unknown whether or not the building exists today.

---

[67] *History of the Air Force Special Weapons Center 1 January – 31 December 1954*, volume 1, v, 98-99.
[68] *History of the Air Force Special Weapons Center 1 January – 30 June* 1956, volume 1, viii-ix
[69] Structures Division, Research Directorate, Air Force Special Weapons Center, "Kirtland Shock Tube Lab: Test Shouldering Nuclear Loads," *Air Force Civil Engineer* 2, 1 (February 1961): 10-11.
[70] Air Force Weapons Laboratory, *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, 155-156. Air Force documentation for the length of the Armour six-foot diameter shock tube is variously stated as 245 and 246 feet. The west-end pressure door accounts for the difference in measurement.
[71] Air Force Special Weapons Center, "Kirtland Shock Tube Lab," *Air Force Civil Engineer*, February 1961, 10-11.
[72] *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, 156.
[73] *Ibid*, 156-157.
[74] *Ibid*, 189-191.
[75] *Ibid*, 191.
[76] Air Force Special Weapons Center, "Kirtland Shock Tube Lab," *Air Force Civil Engineer*, February 1961, 10-11.
[77] *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, 158-162.
[78] Lt. Col. Robert E. Crawford, "The Civil Engineering Branch of the Air Force Weapons Laboratory," *Air Force Civil Engineer* 9, 2 (May 1968): 2-5.
[79] *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, 164-171.
[80] *Ibid*, 194-196.
[81] Air Force Special Weapons Center, *History of the Air Force Weapons Laboratory 1 January – 31 December 1964*, volume 1, 6-7.
[82] *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, 196-210.
[83] Air Force Systems Command, "Air Force Special Weapons Center: A Brief History," four-page typescript, undated.
[84] Crawford, "The Civil Engineering Branch of the Air Force Weapons Laboratory," *Air Force Civil Engineer*, May 1968, 2-5.
[85] Tuttle, *Historic Building Inventory and Evaluation Kirtland Air Force Base*, 1999.
[86] Air Force Weapons Laboratory, *History of the Air Force Weapons Laboratory 1 May – 31 December 1963*, volume 2, 3-6.
[87] *Ibid*, 10.
[88] Joseph Trnka and William Manley, *Historic Building Inventory and Evaluation of Air Force Plant 4, Fort Worth, Texas* (Colton, California: Earth Tech, Inc., and William Manley Consulting, January 1997), 3-29 – 3-30.
[89] Air Force Weapons Laboratory, *History of the Air Force Weapons Laboratory 1 January – 31 December 1964*, volume 1, 4-13.
[90] Crawford, "The Civil Engineering Branch of the Air Force Weapons Laboratory," *Air Force Civil Engineer*, May 1968, 4; Air Force Weapons Laboratory, *History of the Air Force Weapons Laboratory 1 January – 31 December 1965*, volume 1, xvi-xvii. Location of the Gas Bag detonations is not researched here.
[91] Crawford, "The Civil Engineering Branch of the Air Force Weapons Laboratory," *Air Force Civil Engineer*, May 1968, 4.
[92] *History of the Air Force Weapons Laboratory 1 January – 31 December 1965*, volume 1, xix.
[93] *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, 210.
[94] Air Force Weapons Laboratory, "Minuteman I Applications of Protective Construction Research," RTD [Research Test Directorate] Quarterly Systems Support Report 65-3, 31 March 1965, in *History of the Air Force Weapons Laboratory 1 May – 31 December 1965*, volume 2, supporting documents.
[95] *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, xxiii-xxvi.
[96] Crawford, "The Civil Engineering Branch of the Air Force Weapons Laboratory," *Air Force Civil Engineer*, May 1968, 5.
[97] *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, xxv.
[98] Air Force Systems Command, *The Silver Anniversary : Air Force Weapons Laboratory 25 Years of Excellence* (Kirtland Air Force Base: Air Force Weapons Laboratory, 1988), 20.
[99] *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*, volume 1, 28-38, 216-218.

[100] *Ibid*, 38. The two flash x-ray machines installed in Building 418 included a 600 kiloelectron volt (keV) and a 2 megaelectron volt (MeV) machine.
[101] *History of the Air Force Weapons Laboratory 1 January – 31 December 1965*, volume 1, 175-180.
[102] Karen J. Weitze, with Joseph C. Freeman, *Aurora Pulsed Radiation Simulator United States Army Research Laboratory Adelphi Maryland*, HAER No. MD-144 (Plano, Texas: Geo-Marine, Inc., for Army Materiel Command), 1996; Air Force Systems Command, *Air Force Weapons Laboratory*, 1988, 17.
[103] Weitze, *Aurora Pulsed Radiation Simulator*, 1996.
[104] James W. Rawles, "DOD Hardens Standards Against EMP Threat," *Defense Electronics* [Raytheon] 22, 6 (June 1990): 87-91.
[105] Carl E. Baum, "From the Electromagnetic Pulse to High-Power Electromagnetics," *Proceedings of the IEEE* 80, 6 (June 1992): 789-817.
[106] Tuttle, *Historic Building Inventory and Evaluation Kirtland Air Force Base*, 1999, inventory form for ALECS (Building 622). Dr. Baum was also the primary AFWL designer for the sequence of EMP simulators that followed ALECS. By the late 1970s, Dr. Baum had designed 22 EMP simulators. See Note 118. For an example of the early work of EG&G, see: Lt. General Elwood R. Quesada, *History of Operation Greenhouse 1948 – 1951 (Joint Task Force 3)*, 9ff.
[107] Edgerton, Germeshausen & Grier, "EMP Test Simulator Lab," 1964. Also: Air Force Weapons Laboratory, *History of the Air Force Weapons Laboratory 1 January – 31 December 1970*, volume 1, 26, 31-34.
[108] J.C. Giles, Edgerton, Germeshausen & Grier, Inc., *A Survey of Simulators of EMP Outside the Source Region: Some Characteristics and Limitations*, 2 July 1984, revised 23 May 1985. Courtesy of Carl Baum.
[109] *History of the Air Force Weapons Laboratory 1 January – 31 December 1970*, volume 1, 33.
[110] *Ibid*, 26, 28-31.
[111] Giles, *A Survey of Simulators of EMP Outside the Source Region*, 1984 and 1985.
[112] *Ibid*.
[113] Edgerton, Germeshausen & Grier, "Vertically Polarized Dipole II Facility," 21 May 1976.
[114] Giles, *A Survey of Simulators of EMP Outside the Source Region*, 1984 and 1985.
[115] *Ibid*; *History of the Air Force Weapons Laboratory 1 May – 31 December 1970*, volume 1, 26-28.
[116] Baum, "From the Electromagnetic Pulse to High-Power Electromagnetics," *Proceedings of the IEEE*, June 1992, 798.
[117] Karen J. Weitze and Christy Dolan, *Historic American Buildings Survey for the Marine Corps Air Station, Tustin, California*, HABS No. CA-2707 (San Diego: KEA Environmental, Inc., January 2000).
[118] Carl E. Baum, "EMP Simulators for Various Types of Nuclear EMP Environments: An Interim Categorization," *IEEE Transactions on Antennas and Propagation AP-26*, 1 (January 1978): 35-53.
[119] Air Force Weapons Laboratory, *History of the Air Force Weapons Laboratory 1 January – 31 December 1972*, volume 1, 131-139.
[120] McDonnell Douglas, "Trestle Facility Concept Drawings in support of Annex A Facilities Design Concept (DRL A008)," undated.
[121] Air Force Weapons Laboratory, *History of the Air Force Weapons Laboratory 1 January – 31 December 1971*, volume 1, 36-51.
[122] *History of the Air Force Weapons Laboratory 1 January – 31 December 1972*, volume 1, 43-50, 52-67.
[123] *History of the Air Force Weapons Laboratory 1 January – 31 December 1971*, volume 1, 51-64.
[124] Information posted at www.archtechnology.com/history.
[125] *History of the Air Force Weapons Laboratory 1 January – 31 December 1972*, volume 1, 43-50.
[126] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 230-254, 304-310. The protective aircraft shelter program was complex and long-lived, traceable to 1952 and continuous until after the Cold War's end. The role of the AFWL was intricate within the effort, discussed in detail in *Eglin Air Force Base, 1931-1991*. As of 1970, the Air Force had contracted for 1,500 Concrete Sky shelters. As of 1979, NATO countries alone supported 497 hardened TAB VEE shelters, with both programs originating from the efforts within ARDC / AFSC. Interviewed for their roles within the hardened aircraft shelter program were Ken Bell, formerly of NMERI; Thomas Bretz and Dr. Maynard A. Plamondon, formerly of the AFWL; and, Terry Smith, range manager at the UTTR. See the bibliography for Volume II.
[127] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 266-267.
[128] *History of the Air Force Weapons Laboratory 1 January – 31 December 1971*, volume 1, 64-73; Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1971*, volume 3, part 1, 63.

[129] Public Affairs Office, Kirtland Air Force Base, "Air Force Operational Test and Evaluation Center Fact Sheet," September 1999. Posted at www.af.mil/news/factsheets/Air_Force_Operational_Test_an.
[130] Air Force Systems Command, *Air Force Weapons Laboratory*, 1988, 44.
[131] Diane Williams, notes from drawings filed in the civil engineering vault at Kirtland Air Force Base. Buildings on site include 758-767, with additions into 1985-1987.
[132] Air Force Systems Command, "The Air Force Weapons Laboratory (AFWL) 1963-1990," three-page typescript, ca.1990.
[133] Air Force Systems Command, *Air Force Weapons Laboratory*, 1988, 26.
[134] "Advanced Airborne Demonstrator Complex Site and Location Plans," 1 July 1982. The Fiscal Year Military Construction Program (MCP) annotated on the drawings is 1985.
[135] Air Force Systems Command, *Air Force Weapons Laboratory*, 1988, 21.
[136] Air Force Materiel Command, *Phillips Laboratory Facilities*, Phillips Laboratory History Office Pamphlet Series, Number 5 (Kirtland Air Force Base: Phillips Laboratory, History Office, ca.1996); Barron K. Oder, Major Laurel Burnett, and Captain Rhonda Toba, *Phillips Laboratory: Its Origins and Chronology 13 December 1990 – 30 October 1997* (Kirtland Air Force Base: Phillips Research Site, History Office, July 1998).
[137] "W.H. Weiskopf Dies," *Engineering News-Record* 160, 10 (6 March 1958): 29; Carl W. Condit, *American Building Art: The Twentieth Century* (New York: Oxford University Press, 1961), 16, 25, 181.
[138] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 76.

Chapter 9: Los Angeles Air Force Base

Historic Missions of the Cold War

From its beginnings in July 1954, what is Los Angeles Air Force Base in 2003 was, and remains, an atypical Air Force complex of facilities. Many of its most important activities took place at other Air Force bases or in the plants and offices of contractors. Nonetheless, Los Angeles Air Force Base is one of the most significant installations of the Cold War. To understand the American intercontinental ballistic missiles (ICBMs) program, one must understand the workings of Los Angeles Air Force Base. In particular, design and engineering of ICBMs and their associated ground support equipment was handled at Los Angeles Air Force Base (formerly, Los Angeles Air Force Station). "Ground support equipment" included items like the hardened silos and launch control centers (blockhouses) for the emplaced Atlas, Titan, and Minuteman program, for example. These facilities went in throughout the continental United States at operational sites and as test complexes on Air Force bases. Within Air Research and Development Command (ARDC) / Air Force Systems Command (AFSC), Los Angeles Air Force Base maintained particularly vital interactions with the Air Force Flight Test Center at Edwards Air Force Base in Southern California (for engine and stage tests of ICBMs); Air Force Missile Test Center at Patrick Air Force Base in Florida (with the launch sites located at Cape Canaveral Air Force Station) (for full-scale launch tests of ICBMs); Arnold Engineering Development Center (AEDC) in Tullahoma, Tennessee (for multiple developmental tests on ICBM scale-models and components); and, Hill Air Force Base in Utah (for the Minuteman program) (see Volume II, Chapters 1, 3, and 6). Los Angeles Air Force Base also had extremely close ties with the San Bernardino Air Materiel Area (AMA) at nearly Norton Air Force Base. That installation was subsumed under Air Materiel Command / Air Force Logistics Command (AFLC). The strong links to both ARDC / AFSC and Air Materiel Command / AFLC was unusual, and in this regard Los Angeles Air Force Base is also unlike any other installation that operated under Air Force Materiel Command. In October 2001, Headquarters Air Force transferred Los Angeles Air Force Base from Air Force Materiel Command to Air Force Space Command (AFSPC). This action occurred while the current study was underway.

Los Angeles Air Force Base first functioned as a field office for ARDC to develop ICBMs: the Western Development Division (WDD). In its earliest years, the WDD in no way resembled a typical Air Force installation. The Air Force leased (and later bought) space in office buildings in the sprawling Los Angeles basin and from the start maintained these facilities at discontiguous locations. The "installation" did not include any tenant missions, did not have a runway or aircraft (although did have use of a hangar at the Los Angeles International Airport), and did not support military personnel. Los Angeles Air Force Base was strictly a research, development, testing, and evaluation facility run predominantly by civilians and, in large part, contractors. Location near the Southern California offices and test sites of Convair—the firm contracted to develop the Atlas ICBM—was a key factor in its siting, as was the general proximity to aerospace contractors clustered in Los Angeles and to ARDC's Flight Test Center at Edwards to the east. Edwards also featured a major National Aeronautics and Space Administration (NASA) tenant complex on its installation. From very early, ARDC's WDD office, which became the Air Force Ballistic Missile Division (AFBMD) in mid-1957, had important ties to NASA. In 1956, the WDD acquired a military satellite mission from ARDC, another role that would expand over time throughout the Cold War. The AFBMD also began modifying missiles as space booster vehicles during the late 1950s. Its first ICBM, an Atlas, functioned as a first-stage booster for the launching of Air Force and NASA payloads in 1958. NASA turned to the AFBMD and its successors for modifications of ICBMs for boosting its spacecraft and satellites into space. By the date of the shift from ARDC to AFSC in 1961, the AFBMD managed all Air Force long-range ballistic missile missions (intermediate range ballistic missiles [IRBMs] and ICBMs) and space (satellite and space boosters) missions. AFSC separated

and recombined these two halves of AFBMD several times throughout the 1961-1991 period. In 1964, the installation became Los Angeles Air Force Station. In 1987, Headquarters Air Force redesignated Los Angeles Air Force Station as Los Angeles Air Force Base.

Los Angeles Air Force Base and its precursors also had responsibilities for a range of specific programs associated with its missiles, satellite, and space-booster missions for the Air Force and NASA, from mobile basing schemes for an ICBM, to support of antiballistic missile research, to space systems survivability studies, to the NASA Space Shuttle, and to the Strategic Defense Initiative (SDI)—the Star Wars program of President Reagan during the final years of the Cold War. Due to its particular research and development (R&D) missions, Los Angeles Air Force Base worked very closely with military contractors. The installation oversaw their work and managed test launches at Patrick in Florida and Vandenberg Air Force Base in Southern California. Los Angeles Air Force Base was involved in multiple efforts leading to the procurement of the actual weapons systems. Similar to the situation at the AEDC in Tennessee, operations were also partly run by contractors collocated with the Air Force. The infrastructure of the WDD and its follow-ons through the Los Angeles Air Force Base designation of the late 1980s was sometimes leased and was configured as a cluster of discontiguous offices and industrial sites near the Los Angeles International Airport. In selected instances, facilities were further away in greater Los Angeles. Satellite responsibilities included management of a facility in Sunnyvale, in the San Francisco Bay Area to the north, as well as satellite tracking stations dispersed internationally. In the early 1960s, the installation acquired a former Navy aircraft manufacturing plant near its main offices. In 1982, the Army transferred Fort MacArthur to Los Angeles Air Force Station, as well as a former missile plant in Hawthorne (within the Los Angeles basin). Fort MacArthur, along with acquisition of other Army and City of Los Angeles facilities and park lands, became the basis for a more traditional cantonment for the base. The former Navy and Army installations each had Cold War missions during the 1950s and 1960s, and, in the case of Fort MacArthur, an actual Air Force mission in 1950. Los Angeles Air Force Base does not have its own hangars and runways. Historically and in 2003, in a changing pattern, the urban fabric of Los Angeles physically separates the installation's office complexes, industrial buildings, and cantonment areas.

Primary Missions

The primary Cold War missions of ARDC / AFSC at Los Angeles Air Force Base were all focused on the research, development, testing, and evaluation of IRBMs and ICBMs, space launch booster vehicles, and satellites. Missions included:

- management of the Atlas, Titan, Minuteman, Missile X [experiment] (MX [missile experiment]) / Peacekeeper, and Small ICBM (SICBM / Midgetman) developmental programs including test launches, missile site activation, and deployment to Strategic Air Command (SAC);
- management of the Thor IRBM developmental program;
- management of the Blue Scout developmental program (the Air Force version of the NASA Scout, a four-stage, solid-propellant launch research vehicle);
- management of the Space Experiments Support Program (SESP) / Space Test Program;
- support of the Safeguard System Test Targets Program (SSTTP);
- management of an experimental reentry vehicle (warhead) program;
- management of the engineering development for a multiple independently-targeted reentry vehicle (MIRV), allowing for multiple-warhead ICBMs;
- management of the Department of Defense's developmental program for Advanced Ballistic Reentry Systems (ABRES);

- rail- and air-mobile basing, and other mobile schemes for Minuteman I and the Missile X (the MX ICBM) leading to Peacekeeper Rail Garrison;
- management of research and development (R&D) for experimental Department of Defense communications satellites;
- management of the development programs for British and North Atlantic Treaty Organization (NATO) communications satellite systems;
- studies for a Military Satellite System (WS [weapons system] 117L) that evolved into the Discoverer program, the Missile Detection Alarm System (MIDAS) satellite, and the Satellite and Missile Observation System (SAMOS) to provide early warning and observation of hostile missile launches;
- assignment of the 6594th Aerospace Test Wing responsible for military satellite operations in Palo Alto, California, and subsequent management of the Air Force Satellite Control Facility (AFSCF) in Sunnyvale, California, and its worldwide network of satellite tracking stations;
- initial management for the Ballistic Missile Early Warning System (BMEWS), a radar system to provide warning of Soviet ICBM attack over the polar regions;
- Air Force developmental plans for man-in-space projects, and subsequently the full Air Force manned space effort including the Manned Orbiting Laboratory (MOL);
- space systems survivability studies;
- responsibility for the Air Force Space Technology Center at Kirtland Air Force Base in New Mexico;
- assignment of the 6565th Aerospace Test Wing responsible for launching ballistic missiles and space boosters at Vandenberg (later, the Western Space and Missile Center directed through the Space and Missile Systems Test Organization [SAMTO]);
- assignment of the 6555th Aerospace Test Wing responsible for launching ballistic missiles and space boosters at Patrick (Cape Canaveral) (later, the Eastern Space and Missile Center directed through SAMTO);
- development and construction of the Consolidated Space Operations Center for satellite control at Falcon Air Force Base, Colorado;
- contributions to the development of the Anti-Satellite Program (ASAT); and,
- AFSC's primary contributions to SDI.[1]

Tenant Organization Missions

While Los Angeles Air Force Base did not sponsor typical Air Force tenant missions at either its main or annex locations, the installation did make three acquisitions that have Cold War infrastructure. In 1962, Space Systems Division began renovations of a Navy industrial plant (parallel to similar Air Force plants) as its Area B facility. Although the Navy plant dated to 1941 and was originally part of a North American Aviation aircraft plant of World War II, the portion transferred to the Air Force had the majority of its structures added in 1954 for production of the Douglas A-4D fighter aircraft. In 1982, Los Angeles Air Force Station acquired a former Army missile plant in Hawthorne (Annex III: the Lawndale Facility) and Fort MacArthur in San Pedro. At Fort MacArthur two major Cold War missions had been in place during the 1950s and 1960s:

- an Air Defense Command (ADC) command post mission during the early 1950s, followed by emplacement of an Aircraft Control and Warning (AC&W) radar squadron until the end of the decade;
- the Nike-Ajax / Nike-Hercules LA-43 Site; and,
- an Army Missile Master Control Center for 16 Nike-Hercules sites ringing greater Los Angeles.

Los Angeles Air Force Base, in its historical iterations back to its origins as a western field office for ARDC (the WDD), also contributed significantly to NASA Cold War missions, including:

- management of the Thor, Atlas, and Titan booster vehicles developmental (modification) programs (Thor-Able, Thor-Agena, Thor-Delta, Thor-Ablestar, Thor-Altair, Thorad-Agena, Thoras-Delta, Atlas-Agena, Atlas-Centaur, Titan-Agena, and Titan-Centaur);
- a preliminary research program to support NASA manned space flight;
- development of the Television Infrared Observation Satellite (TIROS) meteorological satellite program and transfer to NASA;
- development of the Inertial Upper Stage (IUS) for the Space Shuttle; and,
- development and construction of the West Coast Space Shuttle launch and landing facilities at Vandenberg.

Chronology

Organizational and Real Property Lineage

Today's Space and Missile Systems Center came into existence after the end of the Cold War, in 1992, simultaneously with the creation of Air Force Materiel Command. Just as Air Force Materiel Command recombined the R&D missions of AFSC with those of depot repair, modification, and supply within AFLC, the Space and Missile Systems Center rejoined the ballistic missiles and space missions of the Ballistic Missile Office and Space Division. For the Space and Missile Systems Center, the lineage back to its origins separated and drew together these two basic missions no less than five times (see Volume I, Part II). The Space and Missile Systems Center began as a field office, the WDD, for ARDC. In 1954, the WDD had responsibilities for just one missile system, the Atlas ICBM. In counterpoint to ARDC's WDD, Air Materiel Command had also activated a ballistic missiles unit in Southern California—a Special Aircraft Project Office within the Directorate of Procurement and Production (physically collocated with the WDD). The WDD's first location was in the former St. John's Catholic School on Manchester Avenue in the Inglewood section of greater Los Angeles. During 1955, the WDD moved into buildings near the Los Angeles International Airport on Arbor Vitae Street. The Arbor Vitae site would evolve into Annex I of Los Angeles Air Force Station (Buildings 1-13). The Ramo-Wooldridge Corporation, the managing contractor associated with the WDD, established itself nearby on 40 acres three miles from the Arbor Vitae location at the corner of Aviation and El Segundo Boulevards. The Ramo-Wooldridge site was under construction from 1955 to 1958, and would evolve into Area A of Los Angeles Air Force Station (Buildings 100, 105, 110, 115, 120, 125, and 130). In June 1957, the WDD became the AFBMD, expanding under this organizational name within ARDC until the end of March 1961. ARDC referenced the Ramo-Wooldridge complex (to become Thompson Ramo Wooldridge [TRW]) as the Research and Development Center for the AFBMD[2] (Plates 123-124).

In counterpoint, Air Materiel Command assigned specific AMAs support tasks for the Air Force missiles program as it was unfolding. Air Materiel Command tasked Norton with the Thor, Atlas, and Titan I and II missiles, and associated target drones. Norton would become one of the multiple "locations" of the fragmented units that made up Los Angeles Air Force Base and its forerunners. Norton, which had originated as a depot base under the Army Air Forces Materiel Command in 1942, had continued as the supply and logistics installation for the San Bernardino AMA at the outset of the Cold War. Under Air Materiel Command, Norton had been tied first to Muroc Field (Edwards Air Force Base). Air Materiel Command next consolidated its AMAs in mid-1947, eliminating an AMA role for San Bernardino. In late 1949, Air Materiel Command reactivated the San Bernardino AMA to relieve depot pressures on Sacramento. Still problematic as a depot, Norton became the first base that AFLC chose to remove from its roster during the middle 1960s. In mid-1966, AFLC transferred

Norton to Military Airlift Command, with the depot's primary missiles functions having already shifted to the Ogden AMA (Hill Air Force Base) at the end of 1964 (see Volume I, Part II). Nonetheless, due to its proximity to Los Angeles Air Force Station and the presence of Ballistic Systems Division on base (see below), Norton did keep a missiles mission. As of late 1964, Norton handled the deactivation task for the first generation of ICBMs emplaced in the United States, the Atlas—including removal and storage of the obsolete missiles; preservation of the SAC missile complexes; decisions about reuse of the missile sites; and, disposition of missile property and equipment. The *Wall Street Journal* ran an article in 1967 entitled "Calling Dr. Strangelove: Pentagon Hunts Users for Surplus Missiles" that described this Norton role at mid-decade. An actual example of a deactivation task for Atlas included the retrieval of 270 diesel generators from the SAC Atlas installations, shipping these overseas for reuse in the Vietnam War theater of operations. Norton's role in the deactivation of operational missiles sites continued through the Titan II in the 1980s, with obsolete ICBM shipped to Southern California for storage.[3] This type of work at Norton was directly tied to ongoing efforts in missiles development at Los Angeles Air Force Base, a situation made much stronger through the two installations' physical proximity to one another.

With the change from ARDC to AFSC, the AFBMD divided to become Space Systems Division and Ballistic Systems Division from April 1961 through June 1967 (see Volume I, Part II). Office and research quarters were always at a premium. The repeated organizational changes partially attempted to solve this particular issue. Commander of the AFBMD, General Bernard A. Schriever had recommended a split for the ballistic missiles half of the Division in September 1960. The next month, the Air Materiel Command contracting office, the Ballistic Missiles Center (the follow-on to the missiles unit within the Special Aircraft Project Office), announced a move to Norton. The relocation was the first time the ARDC and Air Materiel Command ballistic missiles groups were at different facilities in the Los Angeles area.[4] In July 1962, the Ballistic Systems Division of the former AFBMD also made a formal relocation to Norton, including the missiles half of its supporting contractor (which by this date was Aerospace Corporation). Ramo-Wooldridge had gone through several name and corporate structure changes between 1954 and 1962. Ramo-Wooldridge first had set up a Guided Missiles Research Division in late 1954. The company had renamed this division "Space Technology Laboratories" in late 1957. Before the close of 1958, Space Technology Laboratories became part of TRW (a merger of Thompson Products and Ramo-Wooldridge). Conflicts of interest started to arise, and in 1960 a new nonprofit corporation, Aerospace Corporation, replaced TRW's Space Technology Laboratories to allow that business to compete for Air Force space and missile contracts.[5] Thus, in July 1962, the Research and Development Center formerly occupied by Aerospace Corporation for both its missiles and space systems work became partially available for Space Systems Division support needs (in what is today known as Area A of Los Angeles Air Force Base).

The separation of Space Systems Division (physically located in Annex I) from Aerospace Corporation (in Area A) in 1962 also stimulated another variation on the basic logistics challenges. To solve the still-problematic discontiguous siting, the Air Force acquired two pieces of property adjacent to the Research and Development Center (Area A), one of which was the middle 1950s portion of a former Navy aircraft manufacturing plant. The acquired property contained facilities designed by the Los Angeles firms of Holmes & Narver and Ralph M. Parsons. The Air Force developed this property as Area B. The original World War II plant was part of a large North American Aviation industrial site at the Los Angeles International Airport. In 1953, the location was still the home plant for the company and its operations continued adjacent.[6] Some of the early 1940s plant buildings transferred to the Air Force. In its Cold War life, the facility had been a Navy Industrial Reserve plant (see Volume I, Part II). As of 1954, when Douglas Aircraft added infrastructure to the Area B site for the manufacture of the Navy A-4D fighter aircraft, the federal government had 233 active plants in its Departmental Industrial Reserves Forty-seven of the plants

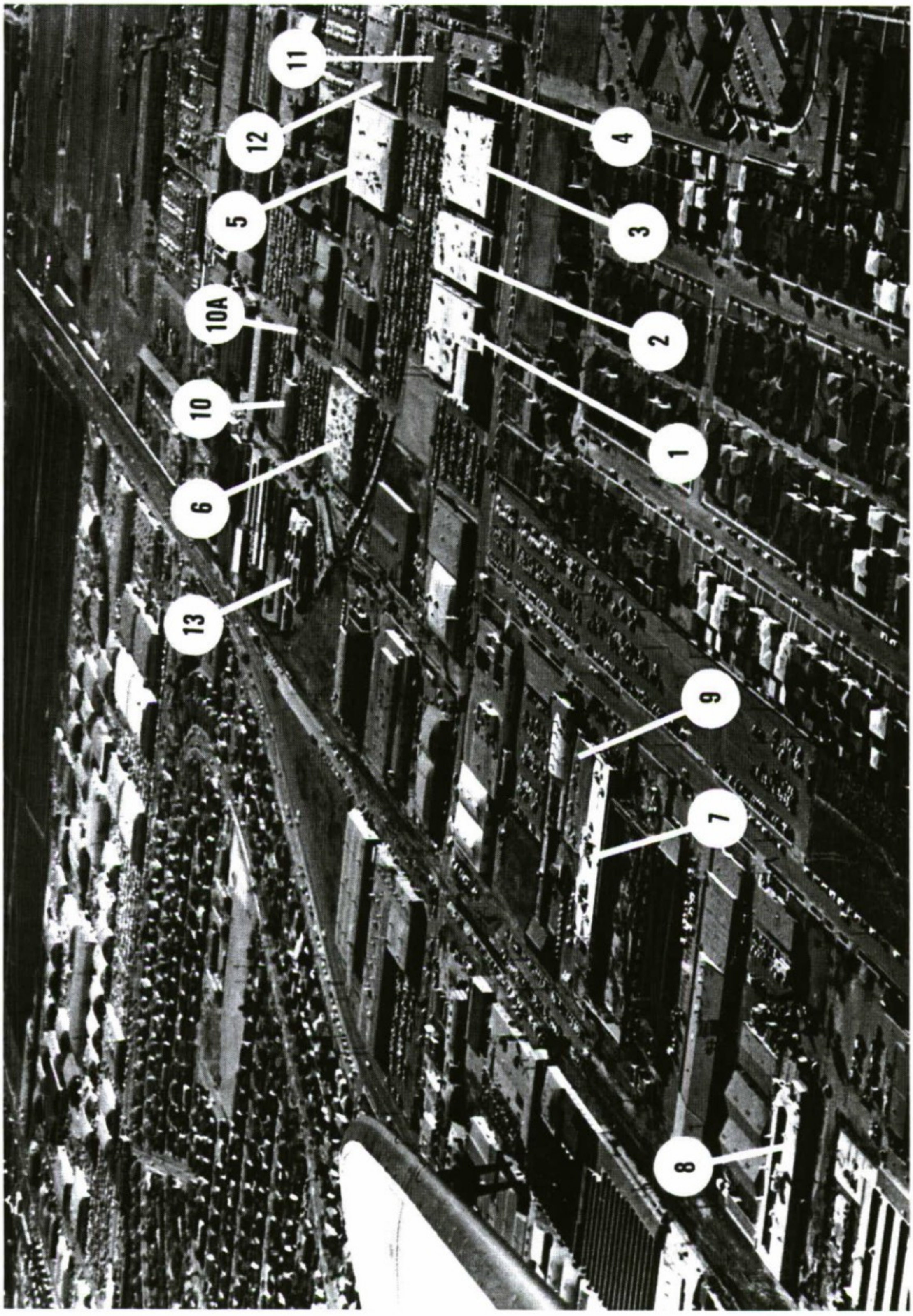

Plate 123: **Aerial View of the Arbor Vitae Site (later named Annex 1, Los Angeles Air Force Station / Base), Los Angeles, 1959. The AFBMD main buildings were 1-4: 5730, 5740, 5760, and 5800 Arbor Vitae; 5-6: 5755 and 5651 96th Street; 7-10: 8820, 9010, 9020, and 9625 Bellanca; 11-12: 5771 96th Street; 13: 9610 Bellanca. AFBMD Headquarters was in Building 3 at 5760 Arbor Vitae. The Ballistic Missile Center of Air Materiel Command was next door in Building 4. Courtesy of the History Office, Los Angeles Air Force Base.**

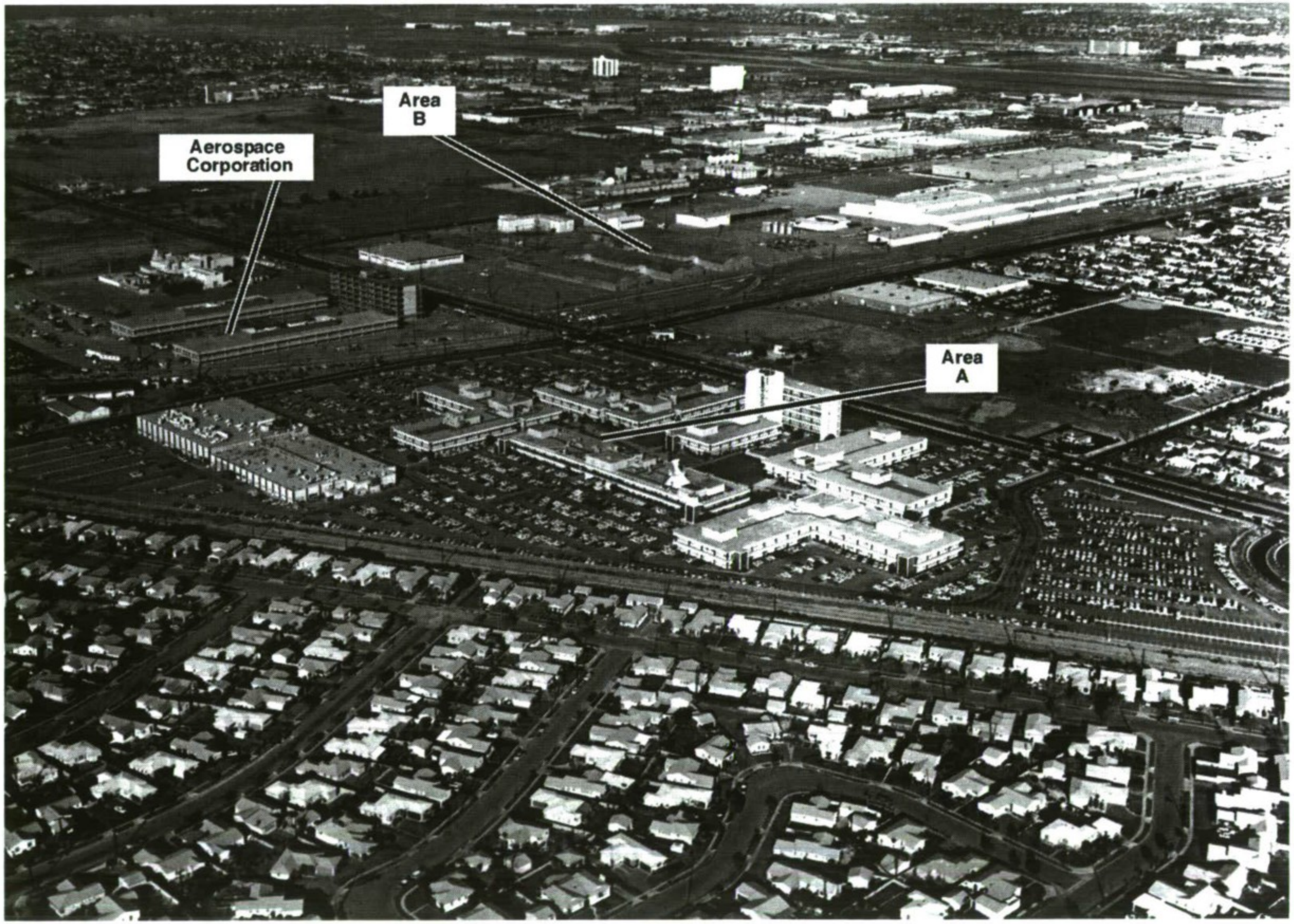

Plate 124: Aerial View of Area A, the Aerospace Corporation Site, and Area B, Los Angeles, ca.1963. Center: Area A (the Ramo-Wooldridge Site), Buildings 100, 105, 110, 115, 120, 125, and 130. Center left: Aerospace Corporation, Buildings A-1 – A-6. Background, center to right: Area B, Buildings 200-244. Annotations added. Courtesy of the History Office, Los Angeles Air Force Base.

manufactured aircraft. Douglas also occupied a second former North American Aviation plant at Palmdale Field near Edwards Air Force Base to the east. There, as a contractor for Air Force Plant (AFP) 42, Douglas produced the Navy A-4D from March 1958 until 1963.[7] Continuing policies of World War II, the government financed plants and their updated equipment for many contractors. Government involvement typically allowed the sustained use of an existing early 1940s facility and provided loans and tax incentives for new construction, such as in Area B.[8]

In its coalescence toward a cohesive Air Force installation, the military side of the organizational structure (Space Systems Division) next occupied the former Ramo-Wooldridge / TRW complex on the southeast corner of Aviation and El Segundo Boulevards (the offices formerly occupied by Aerospace Corporation) and purchased the Navy plant buildings on the adjacent northwestern corner. Aerospace Corporation built an entirely new cluster of offices on the southwestern corner of the same intersection during 1963-1964 (see Plate 124). When AFLC began to shut down Norton as a depot in 1964, AFSC's Ballistics Systems Division remained on base. Earlier that same year, the Air Force designated Space Systems Division's physical sites in greater Los Angeles as Los Angeles Air Force Station. Areas A and B, and Annexes I and II, comprised the "base." (The Air Force excessed Annex II in the early 1970s.) Los Angeles Air Force Station included four separate locations and was strongly tied to a fifth:

- <u>Area A</u>: the Ramo-Wooldridge / TRW Research and Development Center of 1955-1958 (Buildings 100, 105, 110, 115, 120, 125, and 130) (see Plate 124);
- <u>Area B</u>: the Navy plant (Buildings 200, 201, 205, 212, 215, 219, 220, 229, 235, 240, 241, 242, 243, 244, and a commissary) (see Plate 124);
- <u>Annex I</u>: the Arbor Vitae site (Buildings 1-13) (see Plate 123);
- <u>Annex II</u>: the single flight operations hangar of 1961 (Building B-4) at the Los Angeles International Airport assigned to the WDD / AFBMD / Space Systems Division[9] (Plate 125); and,
- <u>Aerospace Corporation</u>: the early 1960s complex adjacent to Areas A and B, but outside the physical property boundaries of Los Angeles Air Force Station.

In July 1967, AFSC once more regrouped its two ("space" and "missiles") divisions at Los Angeles Air Force Station. The reunited halves operated as the Space and Missile Systems Organization (SAMSO) through 1979. The missiles half continued to be physically located in facilities on Norton Air Force Base. After AFLC had left Norton in 1966, Military Airlift Command had become the base host. The missiles half of SAMSO was as a tenant at Norton in 1967-1979. In October 1979, AFSC again separated the space and missiles missions. The command designated "Space Division" and the "Ballistic Missile Office." Finding sufficient physical quarters continued to plague Space Division. During 1982, the Air Force acquired a former Army missile plant in Hawthorne (a city within greater Los Angeles). Similar to the other discontiguous properties of Los Angeles Air Force Station, the missile plant was a mile distant from Areas A and B (the "main base"). Alternately known as Annex III, or the Lawndale Facility, the site joined the installation's properties in 1986 after refurbishment as office space for Space Division's participation in SDI programs (Buildings 80, 83, 84, and 89).[10] A small cluster of three buildings in Torrance, to the southeast of the Lawndale property, was yet another distinct location of Los Angeles Air Force Station of about this same period.[11]

In 1982, the Air Force acquired the discontiguous property of Fort MacArthur, as well as other separately located parcels from the Army and the City of Los Angeles at White Point and Bogdanovich Park. Fort MacArthur dated to 1914 and was located 13 miles south of Areas A and B. The installation had supported a series of Cold War missions beginning in 1950. ADC activated one of its earliest western United States Air Defense Control Centers (ADCCs) for the 27th Air Division (Defense) during autumn 1950 at Fort MacArthur. The physical infrastructure for the Fort MacArthur

Plate 125: AFBMD, B-4 Hangar, Los Angeles International Airport, 1961. View of 1965. Courtesy of the History Office, Los Angeles Air Force Base.

ADCC was unusual. Its buildings were standard not for the ADCC, but rather for either an early warning station or a ground control intercept (GCI) station, both components of the overall air defense network. The ADCC at Fort MacArthur was only temporary, serving in that role until the permanent ADCC was ready at Norton Air Force Base. ADCCs featured Type 4 Operations Buildings, windowless, thick-walled concrete block structures designed by the Chicago firm Holabird, Root & Burgee. Early warning stations, GCIs, and radar stations featured Type 1 or 2 Operations Buildings, similar but more modest structures that selectively functioned as Air Defense Direction Centers (ADDCs). All Type 1 and 2 Operations Buildings could function as ADDCs or as alternates for the next tier up in the chain of command, the ADCC (see Volume I, Parts III and IV). Fort MacArthur's Operations Building is assumed to be a Type 1, functioning first as the temporary ADCC while construction finished up at Norton, then as a GCI station, and finally as a permanent AC&W radar station (the 669th) during the remainder of the 1950s.

In 1954, Fort MacArthur also became one of 16 Nike Ajax / Nike Hercules antiaircraft missile sites ringing Los Angeles. The Army turned over the LA-43 Fort MacArthur Nike site to the National Guard in 1958, following this action with transfer of other Nike sites in the area. The Los Angeles Defense Area became a leader in using the National Guard to man these Army installations. After the change from Nike Ajax to Nike Hercules, the nuclear-capable version of the Nike, Fort MacArthur additionally received the Army command and control mission in 1961 for the 16 Los Angeles Nike sites. The Nike air defense command and control mission operated from a Missile Master Control Center.[12] During the period of 1961-1966, air defense in the United States was a complex mission, with overlapping efforts between the Air Force and the Army. The original Holabird, Root & Burgee Types 1, 2, and 4 Operations Buildings—a major civil engineering project within Air Materiel Command immediately after World War II (see Volume I, Parts III and IV)—saw reuse and

upgrading as air defense command posts a second time in the Back-Up Interceptor Control (BUIC) program that sequentially followed the Semi-Automatic Ground Environment (SAGE) system of the late 1950s. (SAGE had sequentially replaced the ADCC / ADDC system.) The Army's Nike program added another layer of complexity. The Army created Missile Master Control Centers, typically using the Type 1, 2, or 4 Operations Buildings designed for ADC in the late 1940s (see Volume I, Part IV). Fort MacArthur's Type 1 Operations Building, then, continued in its original command post role—only for the Army.

Fort MacArthur, the White Point acreage (renamed Pacific Heights for Air Force use), and Bogdanovich Park acreage (renamed Pacific Crest for Air Force use) each served Los Angeles Air Force Station as much needed cantonment and housing locations. Los Angeles Air Force Station became Los Angeles Air Force Base in 1987. In 1989, the two distinct halves changed names a final time during the Cold War—to Space Systems Division and Ballistic Systems Division. In May 1990, the Ballistics Systems Division ceased to exist, although a small contingent of missiles personnel continued at Norton Air Force Base until that installation's closure in 1995. Personnel at Norton moved to Los Angeles Air Force Base. In mid-1992, what had started as the WDD under ARDC became the Space and Missiles Systems Center, coming full circle to a single organization for the missiles, satellites, and space boosters missions. Real estate history for the organizations that historically comprised Los Angeles Air Force Base had been particularly complex throughout the Cold War, compounded through the interactive roles played by the Air Force and its private industry contractors, and, through the acquisition of both Navy and Army properties that had themselves had major Cold War missions and infrastructure.

History

ARDC's WDD (the earliest physical component of what would be Los Angeles Air Force Station by 1964) had evolved from steady beginnings immediately following the end of World War II. Initial work toward what would develop as the Atlas ICBM pointed to an agency-contractor facility such as the WDD from the outset. In October 1945, Air Technical Service Command at Wright Field in Ohio had requested proposals from the aircraft manufacturers for a 10-year R&D study. Many aircraft companies had formed missiles divisions earlier in the year. Air Technical Service Command was particularly interested in the work of North American Aviation, Bell Aircraft, General Electric, and Consolidated Vultee. Air Technical Service Command's invitation to industry focused on four future missiles with ranges up to 5,000 miles. The 5,000-mile range requirement for the new missiles was a considerable leap beyond the range of the missile leader, the German V (Vergeltung / Vengenance) - 2. As the point of departure, the V-2's range was 200 miles. In January 1946, Consolidated Vultee Aircraft Corporation (Convair) submitted two proposals for a long-range missile: one for a subsonic, winged, jet-fueled missile and one for a supersonic, ballistic, rocket-powered missile. Air Materiel Command (Air Technical Service Command's follow-on) awarded the R&D contract to Convair and named the missile program the MX-774. By late 1947, Air Materiel Command planned to test the MX-774 at Alamogordo Army Air Field (later, Holloman Air Force Base) in New Mexico. The command alternately called the MX-774 "the Atlas." Air Materiel Command developed Holloman as its guided missiles test base during the late 1940s and considered the installation as the possible location for MX-774 test stands.[13] The Air Force abandoned the subsonic version of the missile from further study (the Teetotaler), while Convair focused on its Designs B (Old Fashioned) and C (Manhattan—a name derived from the missile's planned atomic warhead). The MX-774 used the V-2 as its starting point.[14] Air Materiel Command subsequently dropped its plans for a launch site at Alamogordo. (Although the Army's White Sands Proving Ground adjacent to Alamogordo had a launch test area for the captured V-2. A large group of German scientists had worked there while stationed at Fort Bliss in El Paso under the Paperclip program [see Volume I, Part III]). During the late 1940s, competition between the Army, the newly separate Air Force, and the Navy, as well as military budget constraints, complicated long-range missiles development. Waste, duplication, and

reassignments between the military service arms for specific responsibilities helped to shrink the Air Force work toward long-range missiles at the outset of the Cold War. The Research and Development Board's Committee on Guided Missiles, an outgrowth of the Joint Chiefs of Staff's Guided Missiles Committee of 1945, cancelled the MX-774 program in 1947, with full closeout in February 1949. Entry into the Korean War in June 1950 further shifted monies from missiles research.[15]

Nonetheless, work toward the Atlas returned almost immediately and would become the impetus behind ARDC's WDD in Los Angeles. Fiscal Year (FY) funding for 1951 increased for missiles R&D once the Korean War was underway. In January 1951, the Air Force contracted Convair to conduct a two phase study toward a long-range missile, stipulating that Convair address an Air Force preference for either a ballistic rocket or a glide rocket. The project, MX-1593, officially used the name "Atlas." Previously with MX-774, "Atlas" had appeared only informally in monthly progress reports submitted to the Air Force. Convair had continued its Atlas research with its own funds after the Air Force had cancelled the project in 1949, and was prepared for the MX-1593 effort. Now sponsored through ARDC, the Atlas project garnered a range of opinions for its appropriate timetable. ARDC wanted the effort accelerated due to increased intelligence that the Soviets were making marked strides in their development of a powerful rocket engine and in the capabilities of their air defense missiles. Soviet possession of the atomic bomb in September 1949 also encouraged a renewed speed for the development of ICBMs.[16]

After General Dwight D. Eisenhower became President in January 1953, work toward the Atlas became more fully intertwined with ARDC. Under the new administration, the Air Force assigned Trevor Gardner—the agency's Special Assistant for Research and Development—the task of reviewing the development progress for long-range missiles. Gardner pulled together a committee of scientists and engineers in October and appointed Dr. John von Neumann as chairman. The 11-member committee, the Strategic Missiles Evaluation Committee (better known as the Teapot Committee), included engineers Simon Ramo and Dean Wooldridge. The military representative on the Teapot Committee was Colonel Bernard A. Schriever. Several events coincided that affected the committee's report of early 1954 and the formation of the WDD. In late 1952, thermonuclear research had demonstrated that lighter and more powerful warheads were possible. By this date, Convair's experimental Atlas weighed in at 440,000 pounds. With a lighter, more powerful warhead, the Atlas could be cut to 240,000 pounds and would then require less engine thrust to lift it toward its target. The research developments of 1952, coupled with the assessments of the Teapot Committee in late 1953 and early 1954, finally led to a concentrated focus on the Atlas as the single major Air Force missile requiring immediate backing. The proposed crash program argued for an Atlas operational capability between 1958 and 1962. It additionally called for a reorganization of Convair's R&D approach. The Teapot Committee felt that Convair did not have sufficient in-house expertise, and that indeed no single private industrial concern possessed such scientific and engineering knowledge. The committee called for a new management approach which would pull together industry, university, and government representatives.[17]

In late February 1954, representatives of the Air Staff, ARDC, Convair, and the Teapot Committee met to discuss how best an accelerated Atlas program could be set up and managed. The program would also need to support expansion for sequential missiles' development and test. The representatives reached the consensus opinion that the normal workings of government required simplification. They felt that to achieve success three types of organizational structure were possible:

- a university (like the University of California's management of nuclear weapons development at the Los Alamos Laboratory in New Mexico as of 1942 and at the Lawrence Livermore Laboratory in California as of 1952);

- an industrial company (presumably from among the major aircraft companies such as Convair); or,
- a scientific group.

At this juncture, the overarching Air Force goal was a preliminary long-range missile capability by mid-1958, including four operational missiles and two launch sites. In May 1954, the Air Force Chief of Staff, General Thomas D. White, gave the Atlas project the highest Air Force priority. Responsibility for the accelerated Atlas fell to ARDC. Headquarters Air Force officially instructed ARDC to set up a western field office in California in late June. The WDD, established in 1 July 1954, first operated in the former St. John's Catholic School in Inglewood (greater Los Angeles). The ARDC officers of the WDD initially wore civilian clothing to keep the organization's mission low profile.[18]

Structuring of the West Coast operation was unusual and noteworthy. Lieutenant General Thomas S. Power, commander of ARDC, appointed General Schriever to head the WDD. General Schriever was born in Germany. He had immigrated to the United States with his family as a teenager during World War I. As the Assistant for Development Planning in the Office of the Deputy Chief of Staff for Development at Headquarters Air Force, Schriever had served as the military representative on the Teapot Committee in 1953-1954. His record was distinguished. General Schriever's heritage also made it easily possible for him to interact well with the German scientists and engineers working on missiles development through Project Paperclip at Holloman and at the Army's Redstone Arsenal in Huntsville, Alabama—as well as with the Paperclippers at Wright-Patterson and the AEDC who were connected to missiles development. To facilitate the procurement contracting to private industry that the WDD needed in Los Angeles, ARDC requested that Air Materiel Command join its WDD operation by setting up a field office explicitly for this purpose. Directly paralleling ARDC's establishment of the WDD, Air Materiel Command created the Special Aircraft Projects Office in August 1954 (one month after the WDD had become official). The Air Force decided that the WDD would function with the Air Materiel Command Special Aircraft Projects Office lateral to it (for contracting needs).

For other weapons systems development projects, Air Materiel Command directly oversaw a single industry prime contractor to take the system from development and prototype testing to procurement. (For example, the command had developed the B-36 through Convair and the B (bomber) -47 and B-52 through Boeing.) Generally, all parties agreed that this approach would not work well for the Atlas program due to the many and constant changes, special components subcontractors, program slippages, and anticipated large cost overruns. Instead, the WDD oversaw a missiles engineering firm that would function as a deputy to the WDD. The firm would provide systems engineering expertise and technical oversight for the prime missiles contractors, beginning with Convair on the Atlas project. Ramo-Wooldridge Corporation was the intermediate firm that ARDC hired for the job. Both Dr. Simon Ramo and Dean Wooldridge had worked for Hughes Aircraft in Southern California on missiles R&D. The Air Force and the aerospace industry recognized the two men for their successes on the Falcon guided missile. Dr. Ramo also had strong ties to his alma mater, the California Institute of Technology in Pasadena, and to Trevor Gardner. Ramo and Wooldridge had left Hughes to form their own company, Ramo-Wooldridge Corporation, in September 1953. Both men were appointed to the Teapot Committee the next month. At the close of 1954, ARDC's field office, the WDD, and the Ramo-Wooldridge Corporation together comprised the management team for the Atlas. By this date, the WDD was also responsible for consideration of an alternate ICBM (which would become the Titan) and an IRBM (which would become the Thor, based directly on the Atlas).[19]

During the WDD's existence, from July 1954 to the end of May 1957, the division's primary mission was the development of ICBMs for the Air Force. Initially the WDD and Ramo-Wooldridge

managed contracts for the Atlas (Convair) and its liquid oxygen (LOX) propulsion system (developed by the Rocketdyne Division of North American Aviation). Convair was responsible for the airframe of the Atlas and its control system, as well as for the assembly of missile components and the missile itself. In 1955, the WDD (through Air Materiel Command's Special Aircraft Projects Office) extended contracting with Convair to include checkout and testing. Convair hired 30 major subcontractors, 500 smaller contractors, and 5,000 suppliers for the Atlas project, located in 32 states.[20] As a part of its job, Ramo-Wooldridge completed an overall evaluation of related research through past ARDC / Air Materiel Command contracts. By autumn 1954, the WDD proposed that the division address a backup to the Atlas, based on early studies by the Glenn L. Martin Company of Baltimore for a two-stage ICBM. General Schriever also recommended competition between potential ICBMs. In January 1955, the Air Force ICBM Scientific Advisory Committee seconded the proposal for the development of an alternate ICBM. During the same month, the WDD contracted with Aerojet-General Corporation for the development of an alternate LOX propulsion system for the Atlas, to safeguard the program should anything delay or upset the work of North American Aviation.

Throughout the Air Force during the middle 1950s, the agency protected most achievements and critical missions through redundancy. To test nose cones (warheads) for the Atlas, the WDD contracted for a reentry test vehicle (RTV), the X-17. The WDD turned to Lockheed Aircraft Corporation for this task. Nose cone development for the Atlas went to AVCO Manufacturing Corporation, with General Electric later brought on to design and develop the full-scale prototype. The WDD hired AVCO through a sequential contract to design and develop the alternate nose cone for the Atlas. As contracting grew more and more complex, major universities and companies across the spectrum of military contractors became involved. For example, the Air Force hired the Massachusetts Institute of Technology (MIT) to research and develop an all-inertial guidance system for the Atlas, and AC Spark Plug to assist MIT and also to fabricate and test the system. The back-up contract for an alternate guidance system for Atlas went to the Arma Division of American Bosch Arma Corporation. General Electric contracted to design, develop, and fabricate ground-based tracking elements of the radio guidance system for the Atlas. In August 1955, Lockheed launched its first X-17 at ARDC's Air Force Missile Test Center at Patrick. The results were unsuccessful, although the test launch had come barely a year after the WDD was in place.[21]

In mid-September 1955, the WDD added the next ICBM to its developmental roster. Five companies, Glenn L. Martin, Bell, Douglas, Lockheed, and General Electric, competed for the two-stage ICBM, with three finalists, Douglas, Lockheed, and Glenn L. Martin.[22] Air Materiel Command awarded the contract to Glenn L. Martin for development of the Titan ICBM. Simultaneously, the WDD joined Ramo-Wooldridge in a complex of buildings near the Los Angeles International Airport (subsequently known as the Arbor Vitae site, or, Annex I) (see Plate 123). In October, North American Aviation fired its first Atlas engine, from a company test stand in the Santa Susana Mountains near Los Angeles (see Volume I, Plate 42). As the long-range missile program expanded, Ramo-Wooldridge hired more personnel and additionally decided to build new corporation offices in a 41-acre compound three miles from the Arbor Vitae location (Area A), but still near the Los Angeles Airport (see Plate 124). Near the end of 1955, Secretary of Defense Charles E. Wilson set up the Ballistic Missile Committee to review and approve ballistic missile programs. Wilson also acknowledged the recommendations of the Joint Chiefs of Staff to begin development of two IRBMs as stopgap measures while work on Atlas and Titan continued. The IRBM program split between the Air Force (with responsibility for Thor) and a joint Army-Navy effort (for the Jupiter). ARDC assigned the Thor mission to the WDD, from its development through initial operational capability. Development of Jupiter went to the Redstone Arsenal in Huntsville, under the supervision of Paperclipper Wernher von Braun.[23] The WDD (through Air Materiel Command's Special Aircraft Projects Office) contracted with multiple aircraft companies for Thor and its components. Douglas Aircraft became the contractor for the Thor airframe and for missile assembly. In late January 1956,

ARDC prioritized the development of the Thor IRBM and the Atlas ICBM equally.[24] In autumn that year, Air Materiel Command renamed its Special Aircraft Projects Office, the Ballistic Missiles Office.[25]

For Glenn L. Martin's Titan project, the company built a complex near Denver, with the plant an Air Force facility under Air Materiel Command.[26] The Eisenhower Administration had strongly advocated a "dispersal policy" for contracted aircraft and weapons systems firms, seeking to break the concentration of such firms in the coastal Northeast and in Southern California. In part, Air Materiel Command located the Titan plant in Colorado in response to policy directives to contract with companies in the central United States. Other aircraft companies faced the same dilemma for siting their new test facilities, particularly for efforts underway before 1956. The Rocketdyne Division of North American Aviation built its rocket engine test stand and manufacturing plant in Neosho, Missouri, with headquarters for the company remaining in Southern California.[27] In late 1955, the Air Force achieved a waiver from Eisenhower's dispersal policy for all work toward the ballistic missiles program where dispersal would slow down probable operational capabilities. The result was a strengthened concentration in Southern California.[28] In support of Air Force IRBM and ICBM testing needs, plans went forward for launch stands and assembly buildings at the Air Force Missile Test Center at Patrick, missile static test stands at the Marines' Camp Elliott, California (near San Diego), and the 1-A test stand and its follow-ons at the Air Force Flight Test Center at Edwards.[29] To complement the test facilities at Patrick, the Missile Test Center's commander, Major General Donald Yates, also chaired a committee to determine an appropriate location for a ballistic missile development center. The Yates Committee selected Holloman for that mission in May 1955—a location in line with Eisenhower's dispersal policy.[30]

The Air Force had different plans for each of these three sites and their links to the WDD. For the test stands at Edwards, efforts had actually been underway since 1949. The Guggenheim Aeronautical Laboratory at the California Institute of Technology had erected rocket test stands even earlier, in 1940 on leased land in Pasadena's Arroyo Seco Canyon. These facilities served as the direct precursor for Air Force test stands at Edwards. The Guggenheim Aeronautical Laboratory became the Jet Propulsion Laboratory (JPL) in 1944. The JPL constructed its next rocket test stands at Muroc Field (Edwards). The JPL test stand area at Edwards continued as an active and expanded facility during the Cold War, while Air Materiel Command planned for a separate rocket engine test site on base in 1947. Aerojet Engineering Corporation contracted to build the static test stand facility and construction was underway in 1949. The engineering firm of Ralph M. Parsons in Los Angeles subcontracted to Aerojet to design the test stands, control stations, instrumentation, propellant storage and handling provisions, hazardous waste disposal systems, laboratories, and shops.[31] The Experimental Engine Test Station opened at Leuhman Ridge in 1952, with two test stands 1-3 and 1-5. ARDC tested the V-2 engine at Leuhman Ridge during 1953. With the creation of the WDD, ARDC also renamed the Experimental Engine Test Station at Edwards the Rocket Engine Test Laboratory. The first Atlas engine test firing for the WDD at the Leuhman Ridge facilities on Edwards occurred in late 1954 (see Volume II, Chapter 3).[32] In 1955, ARDC added a test stand on Leuhman Ridge to support the WDD's work on the Atlas, Test Stand 1-A.[33] In late August 1956, the WDD conducted the first static test firing of a Thor engine using Test Stand 1-A. The next month, the WDD accepted the Atlas 2A missile from Convair, delivering it to Edwards for checkout prior to captive test firings in 1957 on Test Stand 1-A (see Volume II, Plate 42). (The first Atlas missile delivered by Convair, the Atlas 1A, went through checkout and captive testing at Convair's Sycamore Canyon test site near San Diego) (see Volume I, Part II).[34] Early tests for the Atlas were sometimes dramatic. Test Stand 1-A was severely damaged when an Atlas exploded on the stand in March 1959.[35] In response to the needs of the WDD and its contractors, personnel at the Rocket Engine Test Laboratory at Edwards constantly upgraded the rocket stands to develop individual features such as

flame deflectors, as well as improvements in high-pressure and hazardous propellant equipment[36] (see Volume II, Chapter 3).

ARDC's plans for its Missile Test Center at Patrick were underway in 1955. The command contracted the design and engineering of an Atlas launch complex to Daniel, Mann, Johnson and Mendenhall (DMJM) of Los Angeles (see Volume II, Chapter 1). Designed as a test site for the Atlas, rather than as an operational site, the facilities were the responsibility of the WDD (again with the actual contracts run through Air Materiel Command's Special Aircraft Project Office / Ballistic Missiles Office). While ARDC had initiated construction for launch facilities at Patrick in 1950, the complex was minimal before mid-decade.[37] The role of the WDD in selecting architectural-engineering firms for the missile launch complexes unfolded as singularly important from this date forward. Like the ICBMs themselves, ICBM launch complexes were without precedent beyond the V-2. Through the WDD, Los Angeles firms become the leaders in this specialized construction in a role that extended to expertise in hardening and that carried throughout the Cold War. WDD's follow-on, the AFBMD, also brought in another kind of consulting expertise to meet the challenges of designing and engineering ground support equipment (such as silos and blockhouses) for ICBMs. AFBMD hired engineer Anton Tedesko to assist in the design and engineering of Minuteman facilities and later test stands at Patrick. Tedesko had a long-standing relationship with Air Materiel Command and also served as an advisor to the Air Force between 1955 and 1970 (see Volume I, Part II and Volume II, Chapters 6 and 14).

Three very important Los Angeles firms rose to prominence due to the WDD: Holmes & Narver, Ralph M. Parsons, and DMJM (see Volume II, Chapters 1, 3, and 4). Two of the firms had prior experience in working on highly classified projects for the Army and Air Force. In 1945, Holmes & Narver had been hired to design and engineer the Salt Wells Pilot Plant at the Naval Ordnance Test Station at Inyokern, California (China Lake). The Salt Wells Pilot Plant was the first facility built for the large-scale production of the high explosives (HE) needed for the development of the atomic bomb. The Inyokern site also supported Project Camel for R&D of special components of the implosion assembly, detonators, lens mold design, impact and proximity fuzes and HE components. Bomb drops using "pumpkin" bombs (implosion bomb mockups painted bright orange) filled with HE were part of the testing at Inyokern. Holmes & Narver would also design and engineer infrastructure in the Marshall Islands at the Pacific Proving Ground after World War II for continued testing and improvement of atomic bombs.[38] In the late 1940s and early 1950s, Ralph M. Parsons had participated in critical work for the atomic weapons facilities at the Los Alamos Laboratory in New Mexico and in sensitive biological warfare test infrastructure at Eglin Air Force Base in Florida. Yet, as important as these assignments were, neither of these firms had prior experience in missiles work. DMJM, as far as is ascertained, had no involvement of this type at all. Before the close of 1957, DMJM designed the Atlas launch complex at Patrick, the Thor launch complex at Vandenberg,[39] and the expanded grouping of North American Aviation test stands in the Santa Susana Mountains northwest of downtown Los Angeles. The test stands for North American Aviation included one facility that incorporated a vacuum chamber to simulate altitude conditions for engine operation[40] (see Volume I, Plate 42).

In its relation with the WDD, Holloman took a very different path from either Edwards or Patrick, and illustrated the complexities of long-range missiles development in the middle 1950s. During 1945 and 1946, respectively, the Army and the Navy had begun construction of launch sites for the V-2 at the neighboring White Sands Proving Ground, including large-scale blockhouses. The Navy's launch site featured a deluge component, with a high-pressure flooding system that implied a capacity for static testing. V-2 materiel had started arriving in El Paso at Fort Bliss in 1945. In June 1947, the Army Air Forces had assigned Alamogordo Field the mission of guided missiles testing. Among the first contractors to come to the base to test its missiles were Boeing from Seattle (for the Gapa) and

North American Aviation (for the Nativ). The North American Aviation test site at Alamogordo (Holloman Air Force Base as of 1948) was the Los Angeles firm's only static test stand for the Nativ until the subsequent construction of the Santa Susana test stands—the latter also known as North American Aviation's Rocketdyne propulsion field laboratory. Before 1950, representatives from Boeing, Bell, Martin, Northrop, Convair, Ryan, North American Aviation, Republic Aviation, Aerojet Engineering, and Hughes were all working at guided missile launch complexes built at Holloman. More than 70 percent of the firms running tests at the New Mexico installation were from Southern California.[41] Holloman hosted the Air Force Missile Development Center for Headquarters ARDC by the early 1950s. Not surprisingly, the base was solidly connected to the WDD and its contractors in Los Angeles. For example, Hughes Aircraft tested the Falcon guided missile at Holloman extensively: the Falcon was the missile that made the professional reputations of Simon Ramo and Dean Wooldridge. The location of Holloman in southern New Mexico, however, was not advantageous to the Southern California missile contractors. The site did not sufficiently meet their guided missiles test needs, and became especially cumbersome for planning tests of the very large IRBMs and ICBMs. In addition to the sheer distance from Los Angeles, as well as the remoteness of the site for housing contractors and their families, Holloman posed a problem of range size. For long-range missile testing, an overwater range provided the desired distances of thousands of miles. Yet Holloman was the existing test installation for guided missiles, fit Eisenhower's dispersal requirement, and came recommended through the Yates Committee as the best location for an ICBM missile development center. The Yates Committee projected 9,200 employees for the Holloman missile center, with over $58 million planned for the construction of static test stands alone.[42]

By May 1955, the date of the Yates Committee proposal that Holloman should become the ICBM test base for ARDC, the WDD was conducting siting studies and contracting for test launch complexes across the United States. While Eisenhower's dispersal policy had been intended to force the aircraft and electronics contractors to more widely and evenly establish their technology hubs to lessen American industrial vulnerability to attack, the removal of all such new locations from the immediate coasts was an anathema to the military contractors. Eisenhower's dispersal policy, nicknamed the "California policy," was equally disagreeable to ARDC and the WDD. With the exemption gained in late 1955, the door opened to reconsider the Holloman siting. Before taking action, the WDD hired Holmes & Narver in spring 1956 to conduct a feasibility study for a missiles center at Holloman. The Holmes & Narver study recommended the Holloman location, proposing a budget of over $470 million for new facilities to support the Thor IRBM and the Atlas ICBM. (The original Yates Committee report had also suggested an Institute of Space [Flight] Technology as a part of the missile test base at Holloman. The institute sequentially dropped out of plans for a missiles test installation, reemerging in the middle 1960s at a site immediate to the AEDC in Tennessee [see Volume I, Plate 9].) By mid-1956, the WDD argued that range capabilities required 5,000 miles for ICBMs, with a Pacific island target. The Air Force next overturned the selection process that had focused on Holloman, and the WDD recommended that two coastal installations be built: the first, a major expansion of test facilities already in place at Patrick in Florida, and the second at Camp Cook, the inactive Army installation that would become Vandenberg Air Force Base in Southern California. Vandenberg evolved as the base that Holloman had been destined to become, largely due to the decisions and lobbying of the WDD.[43] Holmes & Narver went on to design the first Atlas launch complex at Vandenberg in 1958 for the Atlas-A.[44]

The two long-range proving grounds, the Atlantic and the Pacific, provided the major military test locations for WDD contracted missiles. Patrick Air Force Base, ARDC's Missile Test Center on the east coast of Florida near Orlando, was first subsumed under Air Proving Ground Command at Eglin (1949-1951). Patrick fell to ARDC in 1951 and remained under ARDC / AFSC throughout the Cold War (shifting to AFSPC in 1992). The installation managed Cape Canaveral as a missile test annex, first as Cape Canaveral Air Force Station and subsequently as Cape Kennedy Air Force Station.

Cape Canaveral is located about 20 miles to the north of Patrick on a barrier peninsula. NASA operated its own test site to the immediate west of Cape Canaveral Air Force Station (today's Kennedy Space Center). Vandenberg Air Force Base, north of Santa Barbara on the California coast, was under construction in 1957. The Air Force sited Vandenberg to the north of the Navy's existing long-range missile test range at Point Mugu near Oxnard. ARDC managed Vandenberg for six months during the second half of 1957 as the installation became operational. Thereafter, Vandenberg became a SAC installation until Headquarters Air Force placed the base under AFSPC in January 1991. The first long-range missile test was a Thor IRBM at Cape Canaveral at the outset of 1957, with launch of an Atlas following in June. The same month, the WDD changed names to the AFBMD. Momentum continued, and in November the Guided Missile Research Division of the Ramo-Wooldridge Corporation became Space Technology Laboratories.[45] By the next year, studies of recirculation effects at the base of the Atlas were underway at ARDC's AEDC in the 40-inch supersonic wind tunnel. AEDC tests used a scale-model of the missile equipped with small rocket engines (see Volume II, Chapter 1) (Plate 126). In September 1958, the Air Materiel Command contracting office for the AFBMD, previously named the Special Aircraft Projects Office and the Ballistic Missiles Office, became the Ballistic Missiles Center. (The Ballistic *Missiles* Office of 1956-1958 was an Air Materiel Command unit, while the Ballistic *Missile* Office of 1979-1989 reported to AFSC [italics added].)[46] In mid-December 1958, SAC fired the first long-range missile at Vandenberg, a Thor IRBM.[47]

Plate 126: Study of recirculation effects at the base of the Atlas ICBM in the 40-inch supersonic wind tunnel at the Arnold Engineering Development Center, Arnold Air Force Station, Tennessee, 1958. Courtesy of Public Affairs, Arnold Engineering Development Center.

As testing for Thor and Atlas achieved greater steady success, the AFBMD signed a Memorandum of Agreement with SAC for the transfer of functions, personnel, units, and bases from ARDC to SAC for initial operational capability and subsequent operations. At Vandenberg, the AFBMD retained responsibility for the construction of technical facilities, as well as for management of R&D activities.[48] The Air Force first planned for three operational ICBM sites, one each in the eastern, central, and western United States. In 1956, the Air Force had called for 10 missiles and launchers by April 1959, with 120 missiles and launchers at 60 sites by January 1960. The planned combined configuration was 80 Atlas and 40 Titan ICBMs. The projected launch requirements were 20 ICBMs within two hours, with 15 minutes reaction time to launch. (In 1956, the Air Force had not yet established a timetable to transfer the operational ICBMs from ARDC / Air Materiel Command to SAC).[49] Work continued toward a family of operational ICBMs. AFBMD's efforts for Titan moved along in phases parallel to its predecessor the Atlas. Preliminary R&D toward the Minuteman ICBM was also underway. The ballistic missiles mission of ARDC / AFSC in Southern California evolved as complex, with multiple interactions with other ARDC / AFSC, SAC, and Air Materiel Command / AFLC installations—as well as with the United States Army Corps of Engineers. Once R&D for a missile system was complete and operational transfers were made to SAC, the AFBMD (subsequently, Ballistic Systems Division) and Air Materiel Command's Ballistic Missiles Center also made arrangements for the transfer of weapons system management to one of Air Materiel Command's depot bases. The AFBMD assigned the initial ballistic missiles logistic support mission to the San Bernardino AMA at Norton in late November 1957. In February 1959, the AFBMD signed over management for the Thor.[50] Before the close of the decade, testing procedures under the jurisdiction of the AFBMD also crystallized through the 6555th Test Wing (Development) (later, the 6555th Aerospace Test Wing / Test Group) at Patrick. The 6565th Test Wing (later, 6565th Aerospace Test Wing) at Vandenberg activated in October 1960.[51]

In July 1959, the AFBMD began working closely with the Corps of Engineers. In this instance, the Air Force appears to have had full control of the contracting for the civil engineering of missiles sites from 1955 through mid-1959, with considerable control exercised even after this date. (The situation is parallel to other specialized civil engineering endeavors involving Air Materiel Command and ARDC / AFSC during the Cold War, particularly during the first decade.) In mid-1959, however, the Corps of Engineers set up a Los Angeles Field Office to coordinate its role in the construction of the remaining operational missiles sites. The Corps' Los Angeles Field Office was collocated in the same building complex with the AFBMD near the Los Angeles International Airport. Relations between the AFBMD and the Corps of Engineers were not good. The AFBMD generally criticized the Corps' management of the construction process. In 1960, the Corps of Engineers created yet another organization, the Corps of Engineers Ballistic Missile Construction Office (CEBMCO). This group was independent within the Corps and supervised missiles site construction. In April 1961, the Air Force and Army formally agreed to place the CEBMCO directly under the operational control of the AFSC Ballistic Systems Division (the successor to the AFBMD, 1961-1967, at Los Angeles Air Force Station). The hierarchical situation remained in place until the CEBMCO finished its construction site management tasks. The Army disbanded the CEBMCO in 1967. The Corps' construction duties had been substantial during the program. The Ballistic Systems Division had placed a CEBMCO office at each major missiles site. CEBMCO performed its construction management job for the Atlas F, Titan I and II, and Minuteman programs.[52]

Throughout the Cold War, the AFBMD and its follow-ons carried forward work for the Titan I and II; the Minuteman I, II, and III; and, the MX / Peacekeeper.[53] By mid-1964, the Ballistic Systems Division at Los Angeles Air Force Station had supervised the research, development, testing, procurement, and site construction for the Atlas, the Titan I and II, and the Minuteman I. Excluding the combined test, training, and operational launch sites at Cape Canaveral and Vandenberg, the AFBMD / Ballistic Systems Division had supervised the emplacement of 821 ICBMs: 113 Atlas, 108

Titan I and IIs, and 600 Minuteman Is. At the close of the 1960s, the operational ICBM force was largely completed for the Cold War: 54 Titan IIs and 1,000 Minuteman I, II, and IIIs.[54] As the Ballistic Systems Division turned over operational sites for Atlas, Titan I and II, and Minuteman to SAC, engineered ground support equipment at the sites was of increasing hardness (placed below ground). Beginning with the Minuteman, ICBMs became much smaller, were cold-launched from within their silos, and were solid-fueled (Plate 127). The first test (tethered) of a Minuteman I in a silo occurred at the Leuhman Ridge engine test stand complex at Edwards in mid-September 1959 (see Volume II, Chapter 3). The Leuhman Ridge facilities included two Minuteman static test silos and an aboveground control center.[55] As of 1963, the Ballistic Systems Division (and its follow-ons) managed development toward the MX / Peacekeeper. The Air Force emplaced these missiles in refurbished Minuteman silos beginning in 1986 near F.E. Warren Air Force Base in Wyoming.[56]

The ARDC / AFSC ballistic missiles mission in Los Angeles continued to be directly tied to testing at the AEDC at Arnold Air Force Station in Tennessee (later, Base) (see Volume II, Chapter 1), Edwards (predominantly static engine tests) (see Volume II, Chapter 3), Patrick (Cape Canaveral), and Vandenberg. Efforts at Arnold included wind tunnel scale-model tests and static engine tests. AFSC built the J-5 test cell at the AEDC for the Minuteman in the early 1960s. After the Cold War, personnel test-fired the Peacekeeper stage II motor in the J-6 test cell (Plate 128).[57] The AFWL at Kirtland Air Force Base in New Mexico was also of prime importance for ICBM testing. Kirtland's support of Los Angeles Air Force Station concentrated on issues of hardening equipment and structures against nuclear weapons effects (see Volume II, Chapter 8). The AFWL, and its contractors, frequently performed analysis for the Ballistics Systems Division and its follow-ons not only at Kirtland, but also on the Hill Air Force Range (after 1979, the Utah Test and Training Range [UTTR]), at sites in New Mexico and Colorado, and at the ICBM operational sites themselves. One example of nuclear weapons effects testing required for the Minuteman was the High Explosive Simulation Technique (HEST) of the middle and late 1960s.[58] For each of the ICBMs developed, work in Los Angeles included studies and improvements of reentry vehicles (nose cones / warheads).

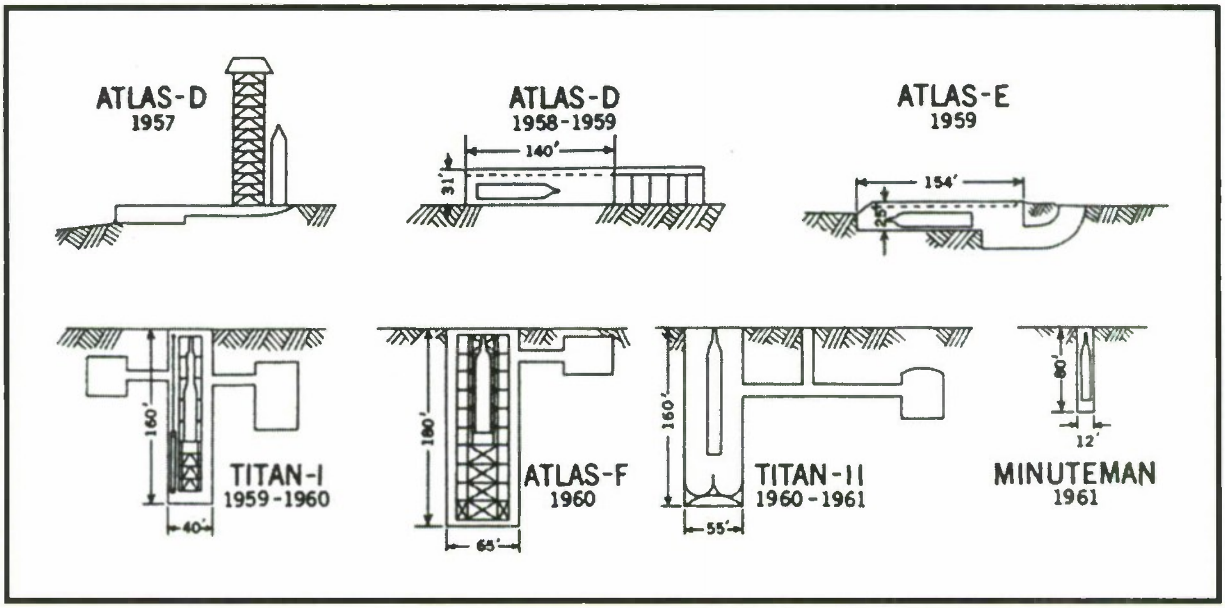

Plate 127: Evolution of launch configurations for the Atlas, Titan, and Minuteman ICBMs. In *The Military Engineer*, November-December 1962.

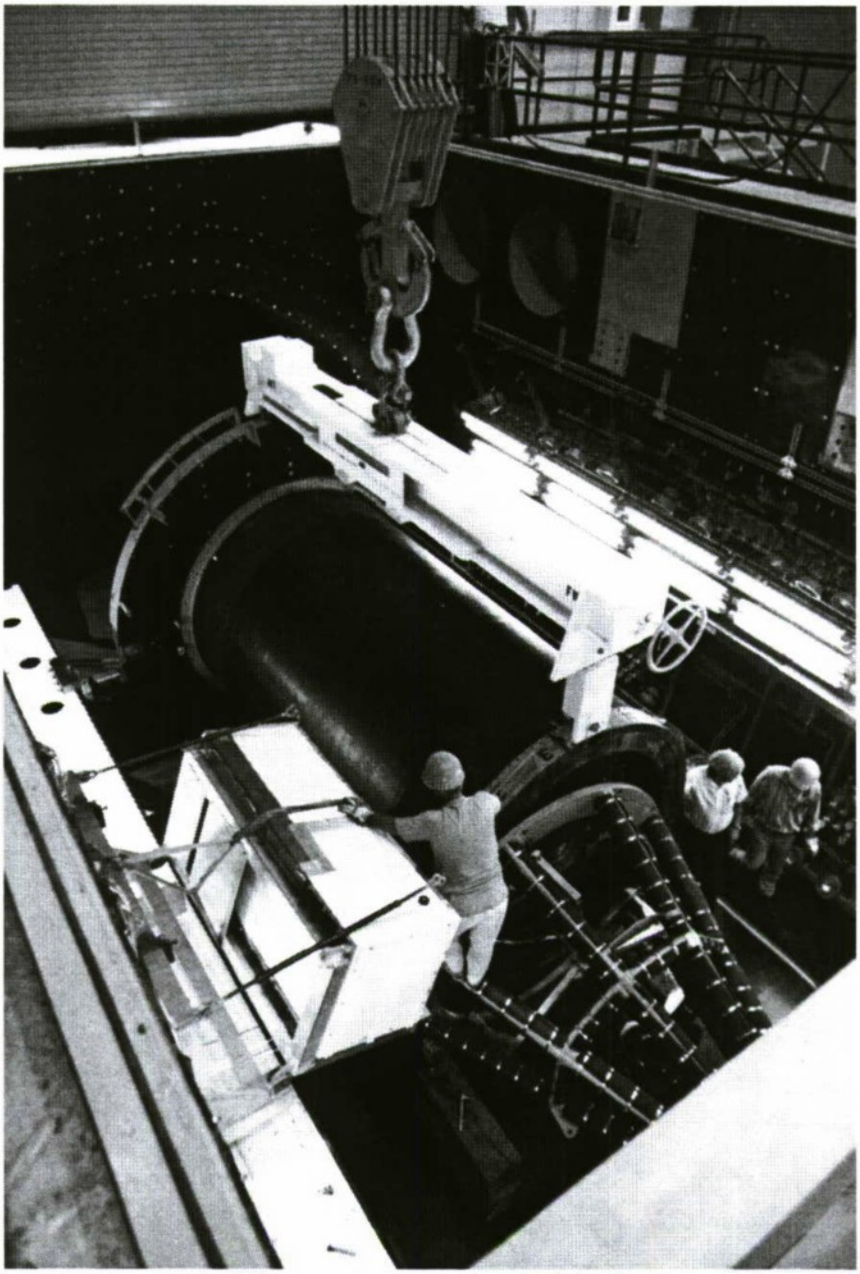

Plate 128: A Peacekeeper stage II in preparation for validation motor firing in the J-6 test cell at the Arnold Engineering Development Center, Arnold Air Force Base, Tennessee, 1994. Courtesy of Public Affairs, Arnold Engineering Development Center.

From the Minuteman III forward, ICBMs also had MIRVs, beginning with the three independently-targetable warheads of the Minuteman III and advancing to the 10 independently-targetable warheads of the MX / Peacekeeper.

From very early, too, the WDD and its successors addressed issues and weapons systems beyond the progressive ICBM. Prominent among these missions during the Cold War was mobile basing for the ICBM. In February 1956, Major General Schriever had initiated a conceptual study for the "mobile" ICBM.[59] By September 1958, Schriever directed the AFBMD to consider a mobile version of the

then-developmental Minuteman. SAC also looked at mobility for the Minuteman ICBM, experimenting with a rail-mobile system in 1959-1961. The command planned for missile trains to run over commercial rail lines supported by selected SAC bases. Hill was AFLC's depot installation for the Minuteman. (Boeing's manufacturing plant for the missile [AFP 77] was collocated on site.) Hill erected sophisticated maintenance testing and storage facilities for the missile on its main base and on the Hill Air Force Range / UTTR (again, with engineering overseen by the Ballistic Systems Division before turnover to Hill). Facilities at Hill included two Minuteman test silos, complete with inert missiles and launch control centers (built aboveground).[60] Not surprisingly, Hill also hosted the rail-mobile test project for the Minuteman, activated at the installation under SAC in May 1960 and named Project Big Star[61] (see Volume II, Chapter 6). In March 1961, however, President Kennedy deferred the mobile Minuteman for operational activation and decided instead to continue with fixed-installation emplacement. Program cancellation for the rail-based Minuteman followed in December.[62] The idea of a mobile Minuteman returned in late 1971 with the Airborne Minuteman concept. In this scheme, the Air Force proposed Boeing 747 wide-bodied jets to carry the ICBMs. AFSC conducted demonstrations for an airborne IBCM using a Minuteman I dropped over water from a C (cargo) -5A on the Western Test Range 20 miles from Vandenberg in late 1974. At this same time, the air-mobile ICBM concept shifted from the Minuteman to Missile X (the future MX / Peacekeeper). SAMSO initiated a formal study of air-mobile basing for the Missile X in late December 1978. Nine months later, SAMSO halted the air-mobile Minuteman program (known as the Minuteman Airborne Launch Control System).[63]

Mobile-basing schemes for an ICBM varied throughout the 1970s and 1980s. For example, in the middle 1970s, a proposed Multiple Aim Point (MAP) basing relied on a deception plan. Although not built, MAP would have hidden 100 MX missiles in several thousand silos. In theory, MAP would have prevented the Soviet Union from being certain of American missile hard target sites. Another strategy that SAMSO addressed was using hardened horizontal shelters, again hiding 200 MX ICBMs in 4,600 shelters. SAMSO contracted Ralph M. Parsons to design, build, and conduct the Missile X Buried Trench Construction and Test Project in March 1977. First steps in the elaborate project included survivability tests using high explosives in wind tunnel facilities at Luke Air Force Base in Arizona for MX shelter-and-trench designs (HAVE HOST). After review of cost studies for the test project to the SAMSO in September, construction of test trenches in the San Cristobal Valley of the Luke Bombing and Gunnery Range began in February 1978. Parsons designed the buried trenches and shelters; Boeing, the trench breakout erection system for the MX. Parsons completed construction in Arizona in mid-November.[64] During the late 1970s, President Carter particularly favored the Multiple Protective Shelter (MPS) program devised by SAMSO for horizontal shelters. The program, however, required very large set-asides of public land in Kansas, Nebraska, Colorado, Nevada, Utah, New Mexico, and Texas. The American public was strongly opposed to the project. After the change in administration to President Reagan, the MPS idea died, and the Ballistic Missile Office turned to placement of the MX in superhardened, refurbished Minuteman silos. A final mobile-basing scheme resurfaced one last time, however, with the Rail Garrison project of late 1986-1991. The Ballistic Missile Office supervised Rail Garrison's test complex at Vandenberg. Construction at the site was not quite complete as the Cold War formally concluded. Rail Garrison, similar to Project Big Star of 1960, proposed to make the MX / Peacekeeper ICBM, with its 10 independently-targetable warheads, rail-mobile with support bases across the United States. Rail Garrison became one of the bargaining chips between the United States and the Soviet Union that formally ended the conflict. On 26 September 1991, the Senate cancelled Rail Garrison. The program was called out for cessation in the Strategic Arms Reduction Treaty (START) of the preceding July (see Volume I, Part I).[65]

Contributions to the BMEWS and antiballistic missile (ABM) defense programs are examples of two other Cold War missions at Los Angeles Air Force Station. Headquarters ARDC assigned the

AFBMD initial management responsibility for BMEWS in November 1957.[66] (The command gave the task of design and engineering development for the long-range radars to the Rome Air Development Center [RADC] at Griffiss Air Force Base in New York (see Volume II, Chapter 12). Efforts toward an ABM system occupied the 1960s into the middle 1970s. In 1962, the Ballistic Systems Division supported the development of the Army's Nike-X ABM through the first Atlas target launch from Vandenberg across the Western Test Range toward the Kwajalein Atoll in the Marshall Islands. By 1969, SAMSO participation in achieving a viable ABM system became formalized as the SSTTP, named for the Army's Safeguard (before 1968, Sentinel) ABM site under construction near Grand Forks Air Force Base in North Dakota (see Volume I, Part I). For SSTTP, SAMSO contracted with Boeing to launch nine obsolescent Minuteman I ICBMs as target vehicles. SAC turned over one of its Minuteman I launch complexes at Vandenberg to SAMSO for SSTTP late in 1969. By mid-1971, SSTTP had launched 20 Minuteman Is from Vandenberg to Kwajalein, where they were intercepted by Army Sprint missiles. Boeing continued to manage the SSTTP effort, with the last ICBM launched in August 1974 from Vandenberg. SAMSO's total launches in support of the Army's ABM testing of its radars and interceptor missiles had been 27 Minuteman Is and seven Titan IIs.[67]

While the accelerated achievement of an operational ballistic missile was the origin of the ARDC mission in Los Angeles, from the middle 1950s forward the WDD very quickly grew to include broader space studies. Satellite support and the modification of IRBMs and ICBMs as boosters for Air Force and NASA research endeavors were the primary efforts of the WDD and its follow-ons. During late 1955, the basic mission of the WDD had begun expanding toward space projects. In mid-October 1955, ARDC's commander Lieutenant General Thomas Power assigned the responsibility for the WS117L military satellite system to the WDD. Two years earlier in May 1953, ARDC had assumed active direction of satellite studies undertaken by RAND, the Douglas Aircraft Research ANd Development think tank in Los Angeles. In December 1953, ARDC had set up Project 409-40, a *Satellite Component Study* for a reconnaissance satellite. Project 409-40 evolved directly into the WS117L effort, with ARDC issuing a program requirement for a reconnaissance satellite in late 1954. From the start, ARDC scientists and engineers understood that the ICBM could place a satellite in orbit by augmenting the basic missile with a powered upper stage. The WDD and Air Materiel Command's Special Aircraft Projects Office awarded the WS117L contract to Lockheed. This first satellite would use an Atlas booster and an Agena upper stage (see below).[68] For a brief period, the Advanced Research Projects Agency (ARPA) took control of the WS117L project from the Air Force, but in late 1959 the Department of Defense assigned all military satellite programs to the Air Force.[69] By the end of the 1950s, the WS117L project had matured as the Discoverer, the SAMOS, and the MIDAS.

The first two of these satellites were for photo-reconnaissance, while the third was part of a missile warning system.[70] The Air Force continued to use the Thor-launched Discoverer in the CORONA intelligence program after early 1962.[71] Like many programs under the Space Systems Division, that of CORONA was related to RAND studies. RAND had originally proposed that a very simple, spin-stabilized satellite could conduct reconnaissance photography, employing a reentry vehicle to return its film and camera to earth.[72] CORONA provided many crucial photographs over the next decade, including the first verification of the Plesetsk Missile Test Range north of Moscow. Unlike the missions associated with Discoverer-CORONA, those of the Atlas-launched SAMOS, a heavier reconnaissance satellite of the early 1960s, have largely remained classified. The MIDAS, an even heavier satellite, used infrared sensors to detect enemy ICBM launches.

> MIDAS would employ eight satellites placed in 2,000-nautical-mile-high polar orbits, equally spaced above the Soviet Union at all times. The data on missiles launches would be transmitted to readout

> stations located in Alaska, Greenland, and England. These MIDAS satellites were to have an operating lifetime of one year.[73]

Work toward a successful MIDAS was slow, but by May 1963 a MIDAS satellite had remained in space for six weeks and had monitored nine Titan II, Atlas, Minuteman, and Polaris ICBM launches. Improvements followed. MIDAS was able to detect American launches of IRBMs and sea-launched ballistic missiles (SLBM)s. TRW won the contract to build the operational MIDAS in 1967-1968.[74] Substantially classified, the MIDAS evolved into the Defense Support Program (DSP) of satellites, ground stations, and mobile ground terminals, active in 2003 to detect and report hostile ICBM launches.[75]

Other satellites developed through the efforts of the Space Systems Division and its follow-ons were ones for communications, weather observation, and nuclear surveillance. Like the satellites derived from the WS117L, these satellites came to initial fruition during the early 1960s with more and more sophisticated individual satellites following throughout the Cold War. Systems well known in 2003, such as the NAVSTAR (Navigation System using Timing and Ranging) Global Positioning System (GPS) developed by North American Rockwell, began as projects under SAMSO (in this case, in the late 1960s).[76] Of note, SAMSO selected Fortuna Air Force Station in North Dakota as the NAVSTAR Control Center in April 1978.[77] The NAVSTAR satellite control center was a 1949-designed Type 2 Operations Building, enhanced to a double-wall, nuclear-protected structure for the BUIC air defense system of the middle 1960s (see Volume I, Part IV). Type 1, 2, and 4 Operations Buildings continued to see this kind of reuse throughout the Cold War. Defense communications satellite work also evolved through phased endeavors to support the tactical communications mission. MIT's Lincoln Laboratory at Hanscom Air Force Base near Boston developed two experimental satellites in 1967-1970 and tested the feasibility of using satellites with small, portable Army, Air Force, and Navy equipment. Both the Navy's and the Air Force's Satellite Communications System (SATCOM) ultimately derived from the phased defense satellite communications efforts managed at Los Angeles Air Force Station. At the conclusion of the Cold War, the Military Strategic Tactical and Relay Satellite System (MILSTAR) satellite provided survivable, jam-resistant communications to tactical and strategic forces and to the National Command Authority. Space Systems Division also worked on projects for British and NATO communications satellites beginning in 1966-1968. NATO satellite efforts continued through the Cold War.[78]

In January 1959, ARDC established a Satellite Control Center south of San Francisco in Palo Alto. These initial efforts were interim only, but by mid-1960 Headquarters ARDC set up the Satellite Test Center in Sunnyvale, near Lockheed's Missile and Space Division. As was true for the ARDC ballistic missiles and space programs in Los Angeles, the satellite mission in Sunnyvale went through several name changes over time, evolving as the Sunnyvale Air Force Station, the Onizuka Air Force Station, and finally Onizuka Air Force Base. The facility was multistory and windowless—distinctly similar in visual appearance to the command and control buildings for SAGE of the late 1950s. The Satellite Test Center also developed a nickname, the Blue Cube (Plate 129). Satellite tracking stations at international locations complemented the center in Sunnyvale. The AFBMD and its follow-ons managed the Satellite Control Center in Sunnyvale until 1987, when the installation became the responsibility of AFSPC. Late in the Cold War, a second satellite control center was under construction at Falcon Air Force Base in Colorado. The Consolidated Space Operations Center at Falcon, with the single mission of satellite control, came on line beginning in 1989. The Falcon satellite control center transferred from Air Force Materiel Command to AFSPC in 1993.[79]

Other space missions for the AFBMD and its follow-ons were many during the Cold War. Work with NASA began in late November 1958 with a formal request from the agency to modify the Atlas as a

Plate 129: Satellite Test Center, Sunnyvale, California, ca.1960. (Later, Onizuka Air Force Base.) Undated view. Courtesy of the History Office, Los Angeles Air Force Base.

booster.[80] Manned space flight, as well as most NASA missions, depended on modified ICBMs to achieve launch. The AFBMD and its successors in Los Angeles directed the modification of Thor, Atlas, and Titan ICBMs to create booster vehicles and added upper stages to develop a family of standard launch vehicles that included the Thor-Able, Thor-Agena, Thor-Delta, Thor-Ablestar, Thor-Altair, Thorad-Agena, Thoras-Delta, Atlas-Agena, Atlas-Centaur, Titan-Agena, and Titan-Centaur (Plate 130). The Air Force and NASA relied on the Thor and the Atlas (with only minor modifications) as space launch vehicles for a very long period. The last use of Thor in this capacity was in 1980; that of Atlas, in 1995. The Titan III, developed from the Titan II, was a particularly powerful booster, with upper stage couplings able to lift very heavy payloads into space. The Titan III became an alternative and backup to the Space Shuttle in the 1980s. ICBM boosters also lifted satellites and other payloads. The modified ICBMs were all expendable launch vehicles. With NASA's work toward a manned shuttle during the 1970s, efforts evolved to include a reusable vehicle. SAMSO contributed to the Space Shuttle program through development of the IUS—a stage for large payloads test-fired at the AEDC during 1977-1979.[81] SAMSO adapted the IUS for coupling with the Titan III (and later, with the Titan IV) expendable system, as well as with the shuttle. For the period beginning in the late 1970s and ending after the Challenger disaster of 1986, Space Division also had responsibility for developing a shuttle launch site at Vandenberg. Contracted to Sverdrup & Parcel, the Vandenberg shuttle launch facilities were planned to accommodate high polar orbit. Changes in the design of the Space Shuttle after Challenger made polar orbits less possible and brought the Vandenberg facilities, then in construction, to a halt.[82]

Additional major programs run through Space Systems Division included those for manned military space projects, research vehicles, and space weapons systems. Although Air Force efforts toward

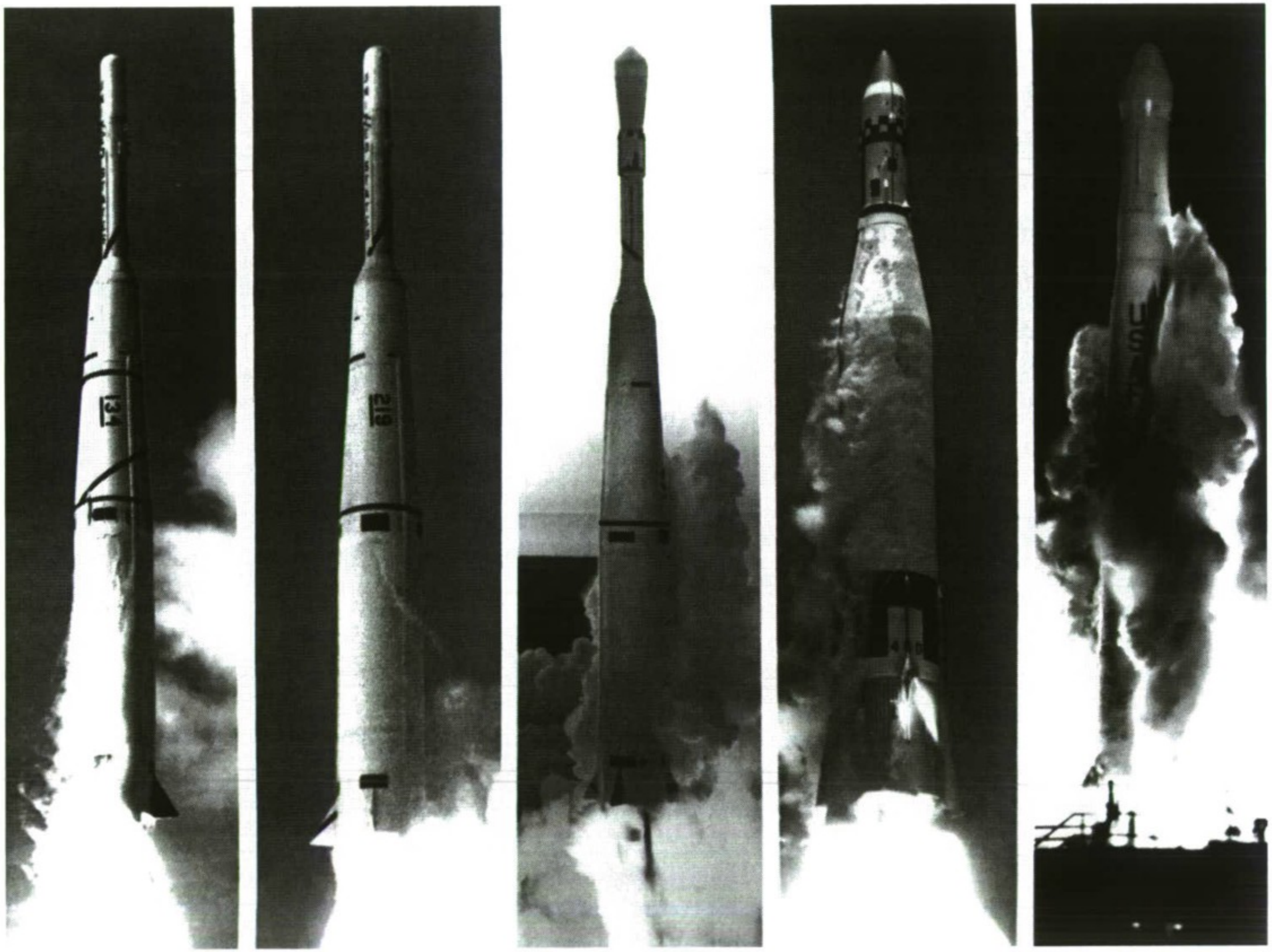

Plate 130: Thor-Able, Thor-Ablestar, and Atlas booster vehicles developed through the AFBMD in 1960. Left to right, launch package projects: Explorer VI (paddlewheel satellite), Pioneer V (solar satellite), TIROS (meteorological satellite), MIDAS II (early warning satellite), and Transit II-A (Navy electronic navigational satellite). Courtesy of the History Office, Los Angeles Air Force Base.

manned spaceflight were reasonably small when compared with those of NASA, several key projects did go through Los Angeles Air Force Station. The MOL and its launch vehicle was one such prominent effort of the middle 1960s. Launch facilities for the MOL were at Vandenberg, with only one launch before program cancellation in 1969. (The MOL launch site became the basis for the sequential Space Shuttle launch area.)[83] The Air Force also developed Blue Scout in Los Angeles, its version of the NASA Scout, a four-stage, solid-propellant launch research vehicle. SAMSO provided spacecraft support to all Department of Defense R&D efforts through its SESP, later renamed the Space Test Program (STP). As for weapons systems, during 1963-1964 Space Systems Division and its follow-ons were responsible for the first antisatellite weapon. The system, Program 437, adapted a modified Thor booster with nuclear warhead to attack enemy satellites or space-based weapons. Testing used ground launch equipment for the Thor, moved from British Thor launch installations to Johnson Island in the Pacific, and modified Thor IRBMs (without live warheads). Four test launches from Johnson Island between 1964 and 1970 brought the weapons system to operational capability under ADC. The ASAT program, which relied upon firing a miniature homing vehicle into space from an F (fighter) -15, followed in the middle 1980s.[84] With the establishment of Space Command in 1982, Space Division at the Los Angeles Air Force Station remained under AFSC, but became closely linked to the new command. As of this date, Space Command (and its follow-on AFSPC) was a main customer for AFSC's Space Division. Many of its operational requirements guided Space Division's late Cold War R&D efforts. Also in 1982, AFSC activated the Air Force Space Technology Center at Kirtland to centralize Air Force space technology planning by coordinating the space missions of the AFWL (Kirtland), the Air Force Rocket Propulsion Laboratory (Edwards) and the Air Force Geophysics Laboratory (Hanscom). The Air Force Space Technology Center reported directly to Space Division at Los Angeles Air Force Station.[85] During the Reagan years, Space Division also worked on SDI programs for surveillance systems to detect and track hostile ICBMs, as well as on efforts toward kinetic energy weapons to destroy the ICBMs when found.[86] By autumn 2001, the space mission dominated the Space and Missiles Systems Center to such a degree that Headquarters Air Force removed the research installation from Air Force Materiel Command and assigned it directly to AFSPC.

Key Associated Architects and Engineers

While missiles and space systems organizations connected to the Los Angeles Air Force Base lineage oversaw contracting for a variety of architectural-engineering firms that worked for the aerospace industry and for the Air Force, the efforts of these firms were all at other installations and locations. (Examples include DMJM's Atlas launch facilities at Cape Canaveral of the middle 1950s and their Thor launch facilities at Vandenberg of the late 1950s, as well as Sverdrup & Parcel's Space Shuttle launch complex at Vandenberg of the same year.) At Los Angeles Air Force Base only two firms are acknowledged as of national significance. Each firm was responsible for the parts of the middle 1950s additions to the World War II aircraft manufacturing plant acquired from the Navy in 1962 and now a part of Area B within the base. Other chapters of Volume II, as noted below, discuss the work of these firms.

- Holmes & Narver, of Los Angeles (see Volume II, Chapter 4); and,
- Ralph M. Parsons, of Los Angeles (see Volume II, Chapter 6).

---

[1] Key missions are presented in three Air Force Materiel Command publications: Timothy C. Hanley and Harry N. Waldron, *Historical Overview Space & Missile Systems Center 1954-1995* (Los Angeles Air Force Base: Space & Missile Systems Center History Office, first published April 1996, reprinted with changes June 1997); John T. Greenwood (with History Office staff assistance), *Space and Missile Systems Organization: A Chronology, 1954-1979* (Los Angeles Air Force Station: Space Division History Office, ca.1984); and,

J. Catherene Wilman, *Space Division: A Chronology, 1980-1984* (Los Angeles Air Force Station: Space Division History Office, ca.1984).
[2] Hanley and Waldron, *Historical Overview Space & Missile Systems Center 1954-1995*, 1997, v, 1-7. The overview addresses historical names and facilities for the full Cold War period.
[3] John C. Lonnquest and David F. Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program*, USACERL Special Report 97/01 (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, November 1996), 313.
[4] Greenwood, *Space and Missile Systems Organization*, ca.1984, 86, 89.
[5] *Ibid*, 24, 42, 80-81; Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960* (Washington, D.C.: Office of Air Force History, 1990), 210-212.
[6] "New Plants to Build Airplanes – Engines – Propellers," *Engineering News-Record* 126, 7 (13 February 1941): foldout between 128 and 129. The journal noted that North American Aviation planned for a plant in this vicinity as of early 1941, with architect and contractor still unselected.
[7] Joseph Trnka, Laura Taylor Lambros, and Norman Rajotte, *Historic Buildings Inventory and Evaluation of Air Force Plant 42, Palmdale, California* (Colton, California: Earth Tech, Inc., and Research Management Consultants, Inc., for Aeronautical Systems Center, Air Force Materiel Command, March 1997), 3-36 – 3-37.
[8] Philip Shiman, *Forging the Sword: Defense Production during the Cold War*, USACERL Special Report 97/77 (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, July 1997), 45, 53-54.
[9] Quinton Engineers, Ltd., *Los Angeles Air Force Station*, 23 December 1964, Tab A: Narrative, and, Tab C: Basic Plans and Data. Tab C includes "Existing Building Schedule," the equivalent of a real property data base —including building numbers, category codes, use, date of original completed construction, square footage, etc.
[10] Air Force Materiel Command, "Comprehensive Plan Los Angeles Annex #3," 15 April 1999.
[11] Air Force Systems Command, "Location of Headquarters Office of the Deputy Commander (AFSC) for Aeropsace Systems, Los Angeles 45, California," undated. The Torrance facility is annotated "71-73," perhaps indicating a contractor user for the location—similar to the notation of "Douglas" for the Lawndale facility on this same map.
[12] Lonnquest and Winkler, *To Defend and Deter*, 1996, 316-318.
[13] Karen J. Weitze, *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970*, Holloman Air Force Base Cultural Resources Publication No. 5 (El Paso: Geo-Marine, Inc., for Air Combat Command, November 1997), 30, 196.
[14] Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, 1990, 44-50.
[15] *Ibid*, 50-68.
[16] *Ibid*, 68-79.
[17] *Ibid*, 95-103.
[18] *Ibid*, 104-107.
[19] *Ibid*, 98-99, 109-118.
[20] Lonnquest and Winkler, *To Defend and Deter*, 1996, 67.
[21] Greenwood, *Space and Missile Systems Organization*, ca.1984, 16-28.
[22] Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, 1990, 128, 131.
[23] *Ibid*, 121.
[24] Greenwood, *Space and Missile Systems Organization*, ca.1984, 28-29.
[25] *Ibid*, 33.
[26] J.S. Butz, Jr., "Plans Detailed for Titan Complex Design," *Aviation Week* 70, 7 (16 February 1959): 27-29.
[27] David A. Anderton, "Missile Engineering," *Aviation Week* 66, 15 (15 April 1957): 52.
[28] Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, 1990, 120.
[29] *Ibid*, 130.
[30] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 77.
[31] Irving Stone, "Architect-Engineers Build for Aviation," *Aviation Week* 65, 15 (8 August 1956): 62-69.
[32] Lonnquest and Winkler, *To Defend and Deter*, 1996, 311.
[33] David D. Earle, Kelly A. Lark, Cole J. Parker, Margaret R. Ronning, and Jackson Underwood, *Overview of Historic Cultural Resources*, volume 2 of *Cultural Resources Overview and Management Plan for Edwards AFB, California* (Edwards Flight Test Center: Computer Sciences Corporation, March 1998), 93-96.
[34] Greenwood, *Space and Missile Systems Organization*, ca.1984, 35.
[35] Lonnquest and Winkler, *To Defend and Deter*, 1996, 311.

[36] Susan Lassell, Shahira Ashkar, and Dana McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB, California* (Sacramento: Jones & Stokes Associates, Inc., for the Air Force Flight Test Center, September 1998), 14.
[37] "Missile Center Expands for Long-Range Flights," *Aviation Week* 59, 7 (17 August 1953): 70-85.
[38] Daniel R. Bilderback and Michael S. Binder, *Early DoD-Sited Nuclear Warhead Infrastructure*, University of South Carolina Legacy Project, May 1999, 28; Necah Stewart Furman, *Sandia National Laboratories: The Postwar Decade* (Albuquerque: University of New Mexico Press, 1990), 92-93; and, Lt. General Elwood R. Quesada, *History of Operation Greenhouse 1948-1951 (Joint Task Force 3).*
[39] Karen J. Weitze, *Request for Determination of Eligibility SLC-2W and SLC-2 Blockhouse Structures Vandenberg Air Force Base* (Austin, Texas: Dames & Moore, for Air Force Space Command, 2 October 1991).
[40] Stone, "Architect-Engineers Build for Aviation," *Aviation Week*, 8 August 1956, 62-69; Richard Sweeny, "Atlas Engine is Fired by Rocketdyne," *Aviation Week* 64, 17 (23 April 1956): 37-38.
[41] Weitze, *Guided Missiles at Holloman Air Force Base*, 1997, 23-46.
[42] *Ibid*, 66-68, 77.
[43] *Ibid*, 78-81.
[44] Karen J. Weitze, *Historic Architectural and Engineering Survey Report Atlas Abres-A* (Austin, Texas: Dames & Moore, for Air Force Space Command, 26 March 1993).
[45] Greenwood, *Space and Missile Systems Organization*, ca.1984, 38-43.
[46] *Ibid*, 57.
[47] Ibid, 59.
[48] *Ibid*, 44-48.
[49] Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, 1990, 123.
[50] Greenwood, *Space and Missile Systems Organization*, ca.1984, 44, 62-63.
[51] Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989), 466, 575.
[52] Lonnquest and Winkler, *To Defend and Deter*, 1996,79-88.
[53] Hanley and Waldron, *Historical Overview Space & Missile Systems Center 1954-1995*, 1997, 9-12.
[54] Neufeld, *The Development of Ballistic Missiles in the United States Air Force 1945-1960*, 1990, 234-238.
[55] Greenwood , *Space and Missile Systems Organization*, ca.1984, 70; Lassell, Ashkar, and McGowan, *Phase II Cultural Resource Evaluation of the Air Force Research Laboratory at Edwards AFB, California*, 1998, inventory forms and maps for Test Area 1-100.
[56] Karen J. Weitze, *National Register of Historic Places Evaluation Peacekeeper Rail Garrison Complex Vandenberg Air Force Base* (Austin, Texas: Dames & Moore, Inc., for Air Force Materiel Command, April 1994), 9-10.
[57] Arnold Engineering Development Center, *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*, 74.
[58] Greenwood, *Space and Missile Systems Organization*, ca.1984, 165, 194.
[59] *Ibid*, 32.
[60] Douglas C. McChristian and Jerome A. Greene, *Arsenal of the Cold War: A Survey of Potentially Significant Facilities on Property Administered by Hill Air Force Base* (Denver: National Park Service, for Air Force Materiel Command, December 1999), 219.
[61] *Ibid*, 148-157.
[62] Greenwood, *Space and Missile Systems Organization*, ca.1984, 95, 101.
[63] *Ibid*, 216, 233, 237, 295, 309.
[64] *Ibid*, 263, 265, 273, 281, 289, 293.
[65] Weitze, *National Register of Historic Places Evaluation Peacekeeper Rail Garrison Complex Vandenberg Air Force Base*, 1994, 9-13.
[66] Greenwood, *Space and Missile Systems Organization*, ca.1984, 43.
[67] *Ibid*, 113, 196, 198, 199, 218, 223, 234.
[68] Curtis Peebles, *High Frontier: The U.S. Air Force and the Military Space Program* (Washington, D.C.: Air Force History and Museums Program 1997), 5-7.
[69] *Ibid*, 33.
[70] Hanley and Waldron, *Historical Overview Space & Missile Systems Center 1954-1995*, 1997, 19.
[71] CORONA is a code name for the project, rather than an acronym.
[72] Peebles, *High Frontier*, 1997, 12-13.

---

[73] *Ibid*, 33.
[74] *Ibid*, 33-39.
[75] Hanley and Waldron, *Historical Overview Space & Missile Systems Center 1954-1995*, 1997, 20.
[76] Peebles, *High Frontier*, 1997, 55-59.
[77] Greenwood, *Space and Missile Systems Organization*, ca.1984, 285.
[78] Hanley and Waldron, *Historical Overview Space & Missile Systems Center 1954-1995*, 1997, 21-25.
[79] *Ibid*, 27; Peebles, *High Frontier*, 1997, 69-72.
[80] Greenwood, *Space and Missile Systems Organization*, ca.1984, 59.
[81] *Ibid*, 279, 300, 305.
[82] Hanley and Waldron, *Historical Overview Space & Missile Systems Center 1954-1995*, 1997, 13-18.
[83] *Ibid*, 29.
[84] *Ibid*, 31.
[85] Wilman, *Space Division*, ca.1984, 2-4.
[86] Hanley and Waldron, *Historical Overview Space & Missile Systems Center 1954-1995*, 1997, 33.

Chapter 10: McClellan Air Force Base

Historic Missions of the Cold War

McClellan Air Force Base served as a maintenance, modification, and repair depot for the Air Force during the Cold War.[1] The Air Force tiered McClellan beneath Air Materiel Command and its follow-on Air Force Logistics Command (AFLC). The associated Air Materiel Area (AMA) was the Sacramento Air Materiel Area (SMAMA), often also used as an alternate name for the base. The installation originated in the middle 1930s, when the Army Air Corps initiated efforts toward establishing an air depot at the location. McClellan was under construction in 1938 and developed into a major air maintenance and supply base for the Army Air Forces during World War II. With only a modest slowdown during the late 1940s, the installation received key missions from Air Materiel Command as the Cold War unfolded. As was the case at all of its depots, Air Materiel Command assigned specific weapons systems to McClellan for maintenance, repair, and modification. McClellan's responsibilities focused on aircraft and radar-electronics equipment—with the latter predominantly associated with Air Force air defense missions. In addition, the installation supported prototype infrastructure similar to selected other bases within Air Materiel Command / AFLC and Air Research and Development Command (ARDC) / Air Force Systems Command (AFSC). The Air Force erected two prototype hangars and an aircraft test facility at McClellan during the Cold War. Sited on the Pacific Coast, McClellan played a key role in logistics and maintenance support during the Vietnam War. The base subsequently took on a role in advisory logistics management for multiple foreign governments, including Australia, Iran, Saudi Arabia, Spain, and Turkey. For long periods during the Cold War, McClellan supported two critical Air Force tenant missions: the Air Force Office of Atomic Energy (AFOAT) in 1949 (with the mission continuing through the close of the conflict) and Air Defense Command's (ADC's) airborne early warning program in 1953 (until transfer in 1976 to Tinker Air Force Base in Oklahoma). McClellan also served as the logistics systems manager for the National Aeronautical and Space Administration's (NASA's) space shuttle program as of the middle 1970s. The base closed in July 2001 as part of the Base Realignment and Closure (BRAC) process.

Primary Missions

The primary Cold War missions of Air Materiel Command / AFLC at McClellan Air Force Base included:

- logistics support for early atomic weapons testing;
- aircraft repair, modification, and shipment;
- repair and supply for instruments, ground-mobile and air-transportable equipment, and radio equipment;
- electronics components testing;
- construction and maintenance for the Aircraft Control & Warning (AC&W) radar program;
- system support management for the air defense programs of the Semi-Automatic Ground Environment (SAGE), the Back-Up Interceptor Control (BUIC) network; the Ballistic Missile Early Warning System (BMEWS); and, the Submarine [Sea]-Launched Ballistic Missile Detection and Warning System (the AN/FSS-7 sites, followed by the Perimeter Acquisition Vehicle Entry Phased Array Warning System [PAVE PAWS]);
- logistics management for the AN/FPS-85 large phased-array radar at Eglin Air Force Base in Florida;
- support for the satellite program;
- long-term system management for the F (fighter) -111;

- aircraft crash and battle damage repair for Vietnam (the Rapid Area Maintenance [RAM] program);
- preparation and shipment of materiel to Vietnam (Rapid Area Supply Support [RASS]);
- assisting foreign governments in materiel management and modernization of air logistics; and,
- x-ray, robotic radiography testing for moisture and corrosion in aircraft parts.

Tenant Organization Missions

Key tenant missions of other Air Force commands at McClellan were:

- AFOAT atmospheric monitoring for above-ground nuclear detonations; and,
- ADC airborne early warning and control.

McClellan also supported NASA during the post-1974 years through:

- system logistics management for the space shuttle program.

Chronology

McClellan had its beginnings in the Wilcox Bill introduced in Congress in early 1935.[2] Planned during 1933-1934 and submitted by Congressman J. Mark Wilcox of Miami, Florida, the bill addressed the need for a larger Air Corps and added air bases. The legislation called for new air installations.[3] The Sacramento Air Depot was one of the original six bases created through the bill. The Air Corps announced the choices in mid-1936. The other five installations included two depots, those at Ogden, Utah (the future Hill Air Force Base) and Mobile, Alabama (the future Brookley Air Force Base).[4] Arthur S. Dudley, the Secretary-Manager of Sacramento's Chamber of Commerce, had promoted Sacramento as suitable for one of the Wilcox bases. Previously, Dudley had successfully kept a nearby installation, Mather Field, open during its difficult years in the 1920s. The Army had closed Mather in 1932 and Dudley first concentrated on reopening the existing airfield rather than on lobbying for a new base (McClellan). Arthur Dudley was a shrewd individual, quick to recognize key concerns of the Army Air Corps. In his advocacy of Mather, Dudley called for the use of its adjacent 50,000 acres as a bombing range. That acreage was covered with gold mining debris and featured an underground mining operation which Dudley argued could be converted to an underground aircraft repair depot. (By the late 1940s, an attempt to design and engineer an underground Air Materiel Command pilot plant came of age, but the project focused on mines east of the Mississippi River [see Volume I, Part III].) McClellan Air Force Base became the Sacramento maintenance and repair depot, while Mather evolved as an Air Training Command installation. (The sought-after bombing range shifted from east of Mather to Tonopah, Nevada—a range attached to Nellis Air Force Base.)

McClellan Field was in planning before the close of 1936. The Army Air Corps dedicated the base in spring 1939. The installation featured three standard maintenance and repair hangars designed to be large enough to resist immediate obsolescence and planned to accommodate the future B (bomber) - 29 (Plate 131). The triple-bay Air Corps maintenance structure (Building 251) was formally titled an Airplane Repair Building. Building 251 featured three tied steel arches of 275-foot span, 250 feet deep. The Air Corps (and subsequently, Army Air Forces) erected the Airplane Repair Building in multiples across its depots. While its clear span was standard, hangar depth varied from the largest dimension of 250 feet deep (as at McClellan) to as little as 190 feet. The unobstructed door openings were 250 feet wide by 37 feet tall. A center lift door of 15 feet square permitted tail clearance for the anticipated bombers. A rear complex of machine shops completed the three joined hangars, with the footprint of the entire structure 925 feet wide by 604 feet deep. The shops were configured as two

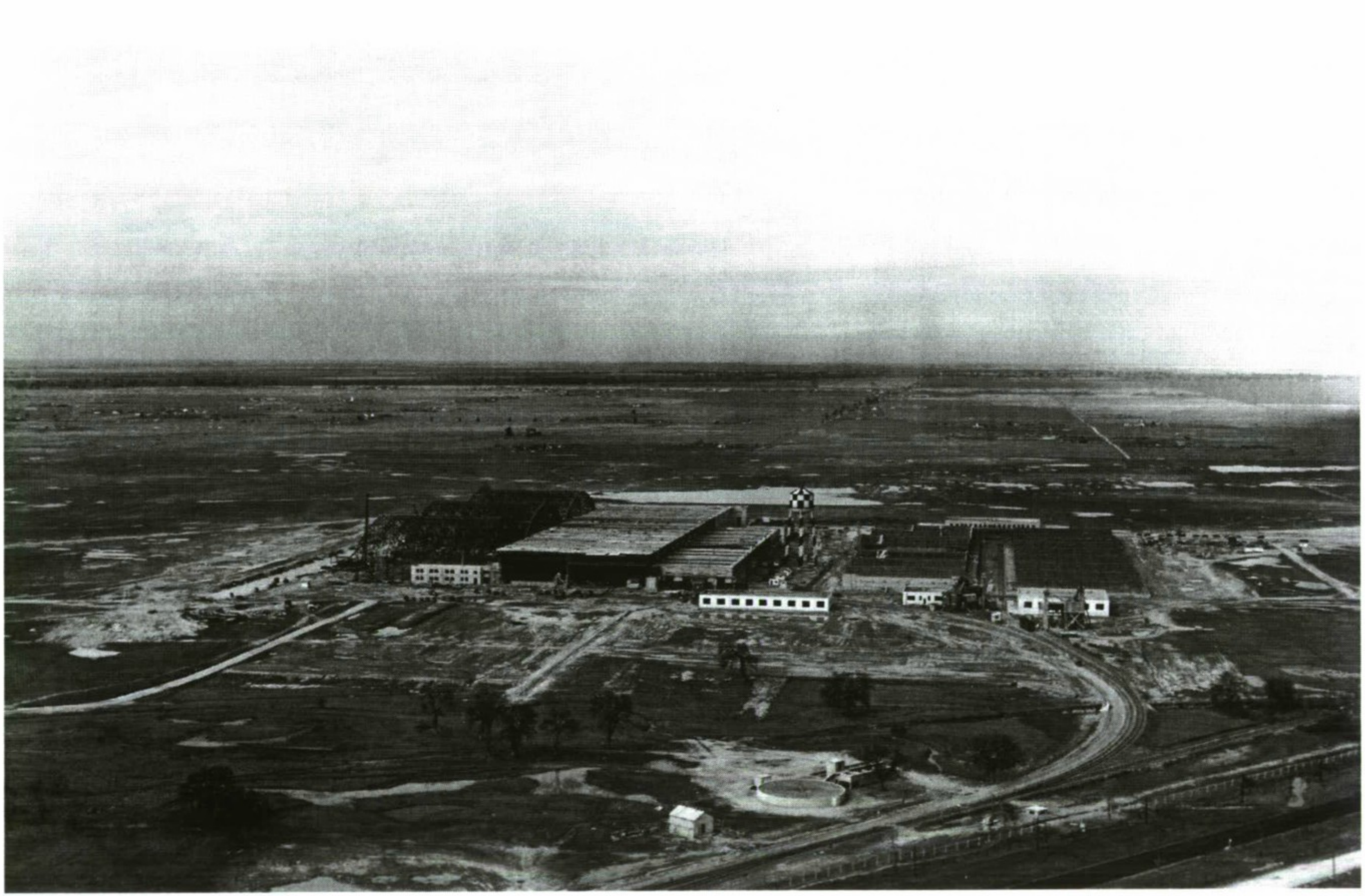

Plate 131: Aerial View of the Sacramento Air Depot at McClellan Field, under construction, 17 February 1938. The Airplane Repair Building (Building 251) and attached shops (Building 252), center. Courtesy of the History Office, McClellan Air Force Base.

long bays behind each hangar. An overhead crane with 150 feet of unobstructed floorspace width complemented each bay. The Air Corps also added a 70- by 202-foot two-story equipment repair building, with basement, to the immediate northeast of the composite hangars and shops. The equipment repair shop (Building 252) featured unusually complete air-conditioning and humidity control which allowed the calibration and rating of delicate instruments.[5] McClellan's cantonment was almost entirely comprised of flat-roofed, reinforced concrete buildings evocative of stipulated concerns in the Wilcox Bill for protective construction. The Air Corps / Army Air Forces sometimes erected the Airplane Repair Building in single configurations, but most often built four hangars in two pairs bracketing an interior shop complex (see Volume II, Chapters 6, 7, 11, 12, 13, and 14). The triple configuration at McClellan was unusual, possibly unique.

Among McClellan's first missions was crating aircraft for shipment to Air Corps bases in the Pacific, and sending supplies to Alaskan airfields and the Panama Canal Zone. When the base opened, McClellan functioned as the only depot for the Air Corps on the West Coast. Important aircraft repaired, maintained, and modified at McClellan from 1940-1945 included the B-17, B-24, B-25, B-29, P (pursuit) -38, P-39, P-40, P-47, and C (cargo) -54. By 1944, facilities included not only the large triple-bay Airplane Repair Building and rear shops, but also a doubled Butler hangar (131 feet wide by 430 feet deep) with an interior assembly line (Building 360).[6] The use of a Butler hangar marked the base's first reliance on prefabricated infrastructure, a strong pattern at the installation during the Cold War years (and generally, across Air Materiel Command / AFLC) (Plate 132). In November 1941, the Sacramento Air Depot at McClellan Field supervised eight California subdepots: at Mather Field in Sacramento and at Stockton, Mountain View, Merced, Lemoore, Taft, Bakersfield, and Victorville. The Army Air Forces placed the subdepots in a north-south line down the San Joaquin Valley to the Southern California desert, with the exception of the lone subdepot in the San Francisco Bay Area at Mountain View. In 1942, Air Service Command opened three more major depots in the West: San Bernardino in Southern California (the future Norton Air Force Base), Spokane in Washington (the future Fairchild Air Force Base), and Ogden in Utah (Hill). After this date, Air Service Command split aircraft, equipment, and supply shipments to the Pacific theater between the depots in Sacramento and San Bernardino.[7]

With the end of World War II in the Pacific, the Sacramento Air Depot ceased work on its production lines. The base continued to support minimal maintenance, repair, conversion, shipment, storage, and disposal duties as assigned, until the installation's opening Cold War mission: logistics support for Operation Crossroads. In planning in August 1945, Crossroads was a complex project set in the Marshall Islands south of Japan. Its purpose was to test the effectiveness of an atomic bomb against naval vessels. Crossroads became official on 12 January 1946. Air Technical Service Command immediately tasked McClellan with logistics. The command trained 110 officers for Crossroads at the Sacramento base.[8] The Crossroads mission quickly expanded from monitoring the effects of detonation against ships, to reviewing effects upon aircraft. The War Department planned Crossroads for 15 May 1946, near the Bikini Atoll. Crossroads was to include test *Able*, an airborne detonation over an array of vessels; test *Baker*, a surface burst; test *Charlie*, a deep underwater detonation; and, test *Detector*, an underwater burst. Construction in the Marshall Islands to support Crossroads was enormous, as was the involvement of the joint services, the Sandia and Los Alamos laboratories in New Mexico, and numerous scientists and mathematicians. Total participating personnel was about 42,000. Due to weather conditions, the full-scale dress rehearsal for the tests did not happen until 24 June 1946. *Able* occurred on 30 June, using a mixed fleet of obsolescent Japanese, German, and American ships—92 target vessels in all. The underwater test *Detector* substituted for *Baker*, and followed on 25 July. Information from the second test was sufficient to cancel *Charlie*.

With the transition from Air Technical Service Command to Air Materiel Command in March 1946, the Sacramento Air Depot became the Sacramento AMA. In early February 1948, McClellan Field

Plate 132: View of McClellan Air Force Base, ca.1968-1974. Foreground: Butler Manufacturing, Repair Hangar (Building 360), ca.1943. Middleground, center: Cold-Proof Hangar for the F-111 (Building 385), early 1970s. Middleground, right: Tent Hangar for non-destructive testing (x-ray) of the F-111, 1968. Courtesy of the History Office, McClellan Air Force Base.

became McClellan Air Force Base. By later in the year, Sacramento's acronym became SMAMA to distinguish the depot from the AMAs at San Antonio (SAAMA) and San Bernardino (SBAMA) (Kelly and Norton Air Force Bases, respectively). (Air Materiel Command sometimes abbreviated the Sacramento AMA as SAMA during 1946-1948.) As part of their responsibilities for the SMAMA in 1948, personnel at McClellan modified B-29 and B-50 bombers for Air Force missions of the early Cold War and worked on P-51s and A-26s for shipment to the Air National Guard (ANG). The SMAMA had 129 B-29s, 206 B-26s, and 53 P-47s in storage at the base that year. McClellan also stockpiled nearly 90,000 pounds of Air Force equipment. McClellan provided logistical support for the California Air Force bases of Castle, Fairfield-Suisun (Travis), Hamilton, Long Beach, March, Mather, McChord, Muroc (Edwards), and Victorville (George).[9]

During the late 1940s, McClellan continued its involvement with atomic weapons testing. In 1947, the multiagency Long Range Detection Committee had stated the need for monitoring atomic tests and was particularly interested in tracking the progress of the Soviet Union toward possession of the atomic bomb. The Air Force Weather Service conducted aerial sampling using adapted B-29s. Operational before the close of the year, the long range detection project was subsumed within AFOAT by mid-1948. During a routine round-trip monitoring flight between Alaska and Japan in September 1949, the 375th Weather Reconnaissance Squadron (WRS) picked up the contamination from the Soviet detonation of *Joe-1* in its paper filters. *Joe-1* was the first atomic test by the Soviets, as well as the first not involving the United States (see Volume I, Part III). AFOAT stationed the 374th WRS at McClellan after the autumn 1949 episode. The 374th WRS was a provisional monitoring squadron that was permanently established as the 55th WRS in 1951. Within AFOAT, the atmospheric detection of atomic detonations was the specific mission of AFOAT-1. With the arrival of the 55th WRS at McClellan, AFOAT-1 also placed its Western Field Office on the base. Working first in woodframe warehouse buildings from World War II, the Western Field Office of AFOAT-1 set up laboratories for the radiological and chemical analysis of contaminated filters and collected air samples brought back by the 55th WRS. By 1955-1957, AFOAT-1 had a permanent laboratory in design and construction at McClellan. AFOAT-1 expanded the technical facilities almost immediately, in 1959.[10] The laboratory (Building 628) was a high-profile project funded in the Military Construction Program (MCP) during Fiscal Year (FY) 1956 and FY 1957, and discussed explicitly by civil engineering staff at Headquarters Air Force.[11] The AFOAT-1 laboratory was 95 percent completed by the end of 1957, with occupancy planned for early 1958.[12] The Western Field Office of AFOAT-1 (later renamed the Technical Operations Division) performed an important, classified mission in its laboratory at McClellan until the end of the Cold War (see Volume I, Part III and Volume Plate 53).

As the 1950s unfolded, McClellan added new missions and infrastructure. During the Korean War, the installation handled repair, maintenance, and shipment to the Pacific for the F-80 and the F-51. The SMAMA continued work on the B-50, and during the war became the first AMA to run depot maintenance on the F-86, a jet fighter-interceptor aircraft.[13] McClellan soon received responsibility for the T (trainer) -33, F-94, and F-82 as well. In 1952, Air Materiel Command cancelled the B-29 repair and modification mission at the SMAMA, simultaneously preparing for receipt of the B-36. During the late 1940s, McClellan had three 7,000-foot runways from World War II (with two of these inactive). Although construction crews had repeatedly beefed up the runways at McClellan Field during the war to handle the movement of B-17s and B-29s to the Pacific theater, the situation post-war required substantial rebuilding.[14] By the middle 1950s, workmen extended the primary north-south runway to 10,300 feet. Plans moved forward to acquire a double-cantilever hangar, the hangar designed for the B-36 and capable of housing a variety of large aircraft. The first B-36s arrived at McClellan in August 1953 for weighing and balancing to achieve proper instrumentation—a task appropriate to the high-tolerance equipment repair building attached to the Airplane Repair Building

of 1937-1939 (Building 251). A double-cantilever hangar (Building 1071) was under construction in 1954. This version of the double-cantilever hangar, designed by the Kuljian Corporation for over 50 Air Force installations in late 1951, could house portions of four B-36s for maintenance. Personnel maneuvered the aircraft in an alternating pattern of nose-in, tail-in through the motorized recessing doors across both primary façades of the structure[15] (see Volume I, Part IV). The B-36 mission stayed at McClellan for only a brief period. The installation next used the double-cantilever hangar for maintenance of the EC (electronics cargo) -121 (Plate 133). The XC-99, the experimental cargo version of the B-36 based at Kelly in San Antonio, may also have undergone maintenance in the double-cantilever hangar for a brief period after 1956. The XC-99 supported the Korean War effort between July 1951 and May 1952, and made trips twice weekly to McClellan from the early 1950s into 1957 (see Volume II, Chapter 7).

As of autumn 1953, the second large-aircraft mission of the initial Cold War years arrived at McClellan: the 4701st Airborne Early Warning and Control (AEW&C) Squadron. The 4701st AEW&C Squadron was a provisional unit equipped with the EC-121D. The EC-121 carried radar and communications equipment in its tall center dome. Its mission was to sustain an air defense barrier several hundred miles off the coasts of the United States. The first apron configurations for the 4701st AEW&C Squadron at McClellan were, like those for the installation's B-36 mission, somewhat improvised. Base personnel erected three pair of C-74 / C-124 wing docks to the south of the double-cantilever hangar along the edge of the apron. The docks were a standard Air Force structure and could be adapted for the C-97, C-124, B-29, and B-50[16] (Plate 134). While these docks were marginal for the EC-121, personnel used the structures for maintenance shelters until more permanent nose docks could be erected adjacent to the double-cantilever hangar (see Plate 133). The AEW&C mission at McClellan never received permanent infrastructure, with the exception of the double-cantilever hangar. In January 1955, the provisional 552nd AEW&C Wing replaced the 4701st AEW&C Squadron on base. The 552nd AEW&C Wing occupied 15 rigid-frame steel buildings (probably Butler in type) adjacent to the early wing docks. The 552nd AEW&C Wing augmented its area with 19 prefabricated Jamesway hutments[17] (Plate 135). The 552nd AEW&C Wing became a major organization at McClellan in July. The Air Force assigned the 963rd, 964th, and 965th AEW&C Squadrons to the 552nd AEW&C Wing by August. During 1956-1957, the 552nd AEW&C Wing acquired eight nose docks to replace those of 1952-1953. While larger and enclosed, the docks (Buildings 1020-1023, 1027-1028, 1032-1033) were still prefabricated construction designed originally for aircraft of the late 1940s and early 1950s—the B-29, B-50, and KC-97. The docks were hand-me-downs, reused by ADC for its AEW&C mission at McClellan. Holabird, Root & Burgee, the firm hired by Air Materiel Command for the ADC first-generation Air Defense Control Centers (ADCCs) and Air Defense Direction Centers (ADDCs) (see Volume I, Parts III and IV), used prefabricated units manufactured by the Farm-Rite Implement Company in Chicago as the basic structure for the AEW&C nose docks[18] (see Plate 133). Use of prefabricated, "economy" infrastructure that could be easily shipped to site, or moved to a new location at a later date, was a character trait of ADC (for example, the command's Butler alert hangars). The practice was even more prevalent within Air Materiel Command, particularly at depot installations such as McClellan.

The AEW&C mission was a significant one within ADC. The sister wing of the 552nd AEW&C was the 551st AEW&C Wing at Otis Air Force Base near Boston (see Volume I, Part IV). The 552nd AEW&C Wing added the 966th AEW&C Squadron at McCoy Air Force Base in Florida to its responsibilities in 1963. (The 963rd, 964th, and 965th AEW&C Squadrons were all physically based at McClellan.) In 1968, when Air Defense Command changed to Aerospace Defense Command, the 552nd AEW&C Wing was the only wing equipped with EC-121s remaining in the Air Force. Its squadrons were located in California, Florida, Iceland, and Korea. The wing's international early

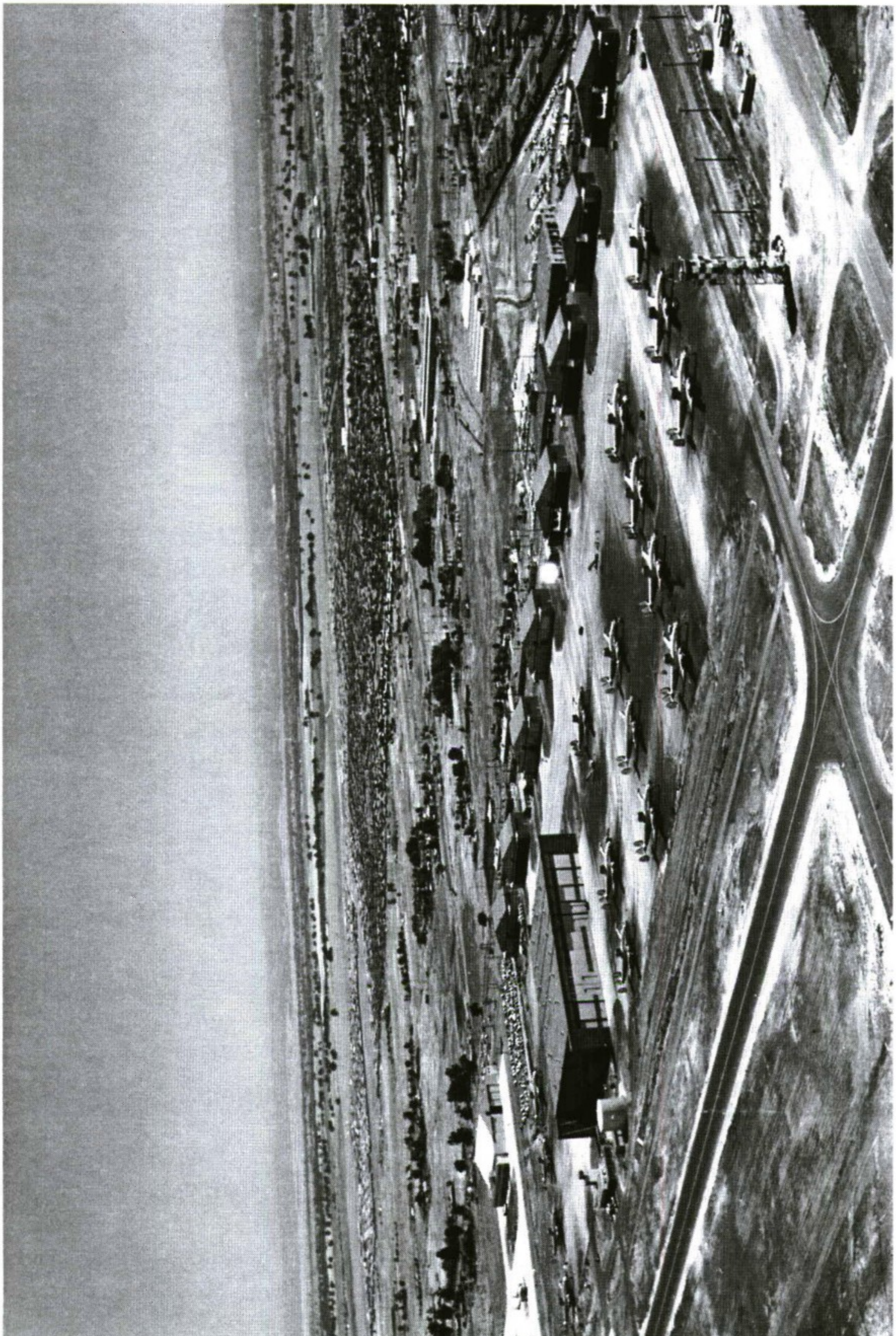

Plate 133: Kuljian Corporation. Medium, Non-Expansible Double-Cantilever Hangar (Building 1071), McClellan Air Force Base. Designed in 1951, constructed 1954. EC-121s of the 552nd AEW&C Wing parked in front of the hangar. Farm-Right Implement Company Nose Docks (Buildings 1020-1023, 1027-1028, 1032-1033), 1956-1957, middleground to right. Courtesy of the History Office, McClellan Air Force Base.

Plate 134: Two Pair of C-74 / C-124 Wing Docks, McClellan Air Force Base, 1952-1953. Today removed. Courtesy of the History Office, McClellan Air Force Base.

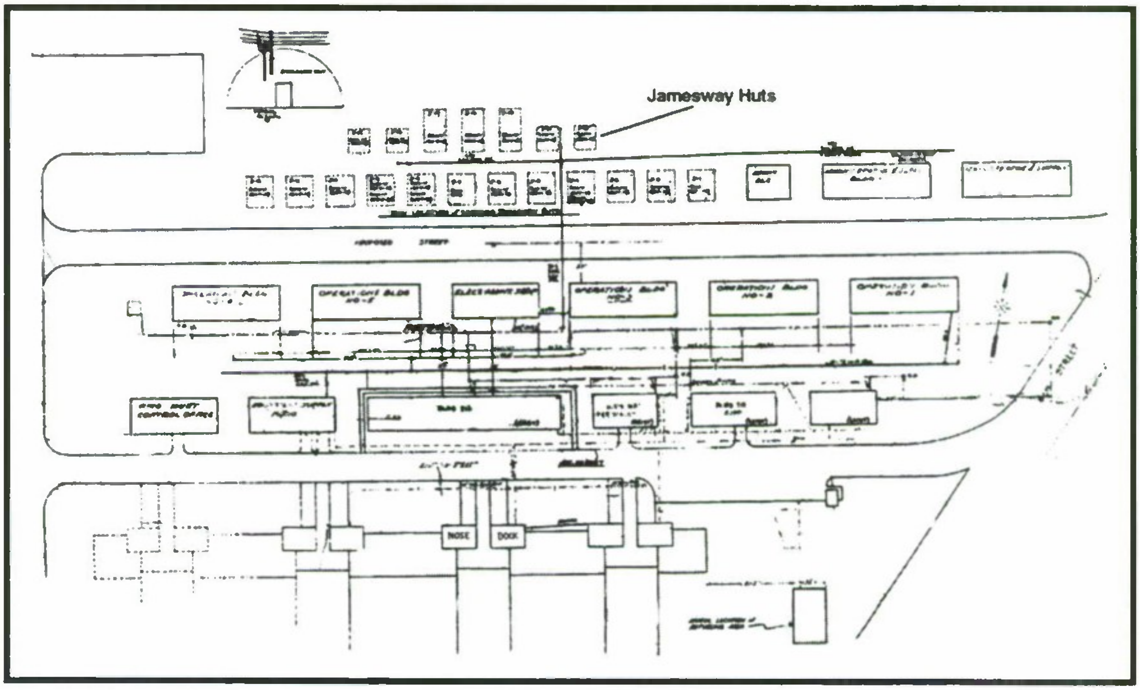

Plate 135: Interim ADC Facilities for the 552nd AEW&C Wing, McClellan Air Force Base, 9 January 1955. Annotation added. Courtesy of Civil Engineering, McClellan Air Force Base.

warning mission had expanded to a variety of duties. The 552nd AEW&C Wing's responsibilities included

> [f]illing in for inoperative land based radar sites, providing coverage in gaps of land based radars, special coverage of active areas, coverage of the first manned space flights, surveillance of VIP aircraft on overseas deployment or providing radar surveillance and control of fighter aircraft...overwater.

During the Vietnam War, the 552nd AEW&C Wing sent men and aircraft to the Pacific during 1965-1970 to aid in tactical operations against North Vietnam.[19] The 552nd AEW&C Wing ceased operations at McClellan in early 1976. The wing subsequently reactivated at Tinker for a continuing airborne early warning air defense mission with later-era aircraft (see Volume II, Chapter 13).

During the middle and late 1950s, McClellan continued to receive major aircraft modification missions and also began significant maintenance, repair, and overhaul efforts for air defense radar systems. The base added key infrastructure and continued runway improvements to support these increased responsibilities. The two primary aircraft projects were the F-86D and the B-47. Project Pull Out of 1954 included improvements to the fire control system, automatic pilot, engine, and drag chute for the F-86D. The SMAMA handled 648 F-86Ds for Pull Out, while the North American Aviation plant responsible for the manufacture of the fighter aircraft processed another 480 of the planes through its facilities in Fresno.[20] In a second major aircraft project, Milk Bottle of 1958-1959, personnel at McClellan disassembled, repaired, reassembled, and flight-tested the B-47. Specific problems included severely corroded wing mounts, and fused nuts and bolts. While McClellan served chiefly as a fighter aircraft support depot, this B-47 mission came to Sacramento nonetheless. Air Materiel Command had designated the Oklahoma City AMA at Tinker as the prime system manager for the B-47, but that depot was overloaded with extensive maintenance for Strategic Air Command's (SAC'S) B-52 and could not take on the B-47 assignment. Both the B-47 and the B-52 were Boeing aircraft—and typically during the middle 1950s Air Materiel Command clustered its depot assignments by manufacturer, a methodology that would have placed both the B-47 and B-52 missions at Tinker. Disassembly, repair, and reassembly of the B-47 took place in the late 1930s Airplane Repair Building on the eastern side of McClellan (Building 251) (see Plate 131)[21] For flight test of the bomber after repair and modification, Air Materiel Command erected a new steel, trussed-arch hangar on the western side of the base in an area set apart for the mission.

The flight-test hangar (Building 704) had a 250-foot clear span and was 240 feet deep. A one-story support area 130 feet wide by 240 feet deep was attached at one side. Erected from precast reinforced concrete panels, the flight-test support facilities included a variety of instrumentation, radio, and mechanics shops, offices, a cafeteria, a conference and training room, a large locker area, and a pilots' lounge. The majority of the individual precast panels were 11 feet 11 inches wide by 24 feet 7.75 inches tall. (The slanted roof of the support facilities necessitated panels of a decreasing height for the south façade.)[22] In construction in late 1958, the hangar supported flight testing of the B-47. The structure also was a prototype hangar that Air Materiel Command was evaluating in 1957 to replace the double-cantilever hangar of 1951 (Plate 136).

> Criteria for a new flight test hangar have been developed for McClellan AFB [Air Force Base] to replace old type double cantilever hangar now void. This new hangar will provide a clear span and full cover for all type aircraft up to and including the B-52.[23]

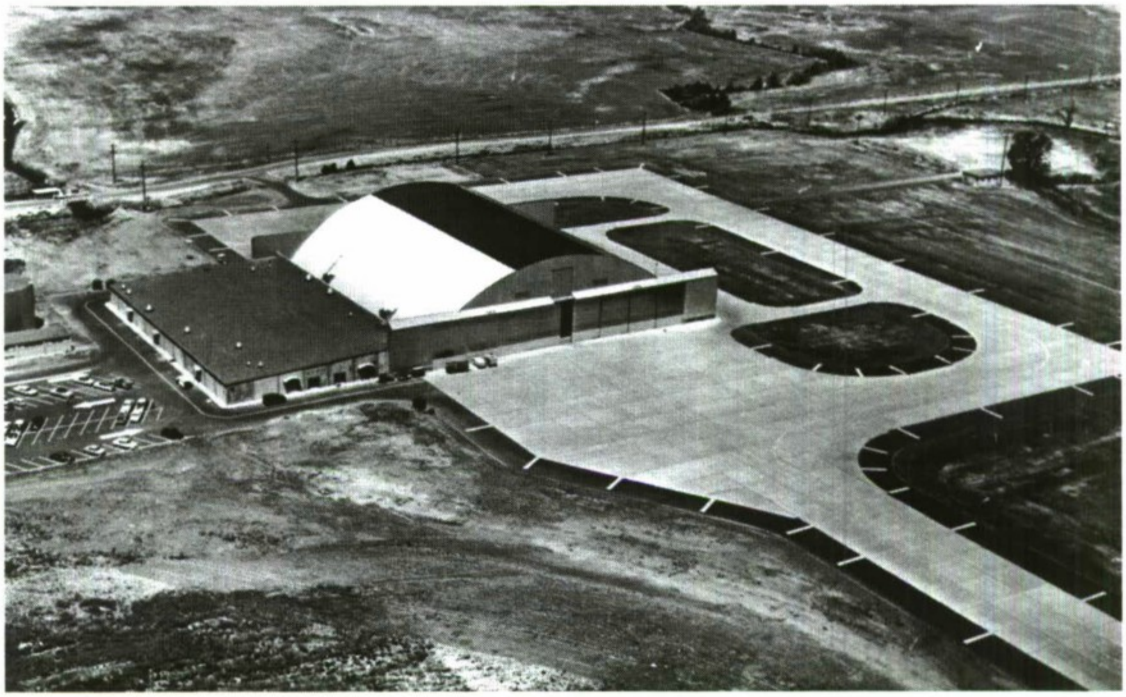

Plate 136: Roberts & Schaefer (attributed). Flight-Test Hangar (Building 740), McClellan Air Force Base, 1958. Courtesy of the History Office, McClellan Air Force Base.

Construction technology adopted for the prototype hangar was provocative and emphasized:

- speed of work on site;
- uniform and interchangeable components;
- lower skilled labor requirements; and,
- cost efficiencies.

At this same time, the Air Force was trying out similar precast concrete-panel technology for many of its buildings under construction at Lajes Air Base in the Azores. The steel-arch component of the structure also was innovative, with three other hangars of 1956-1959 directly related to the prototype at McClellan.

While the architectural-engineering firm responsible for the design and engineering of the flight-test hangar at McClellan is not yet fully verified, all indications point to Roberts & Schaefer of Chicago—the firm also handling the Air Force commissions at Lajes.[24] Robert Zaborowski and David Billington, both of Roberts & Schaefer, were the lead engineers for the precast panel design on the overseas work, while the steel arch hangar is identical to the contemporary work of Roberts & Schaefer's lead engineer, Anton Tedesko. Tedesko had designed three steel-arch hangars with a 300-foot clear span for Idlewild Airport in New York in 1949. The Idlewild hangars were the largest steel arched hangars in the world at the time of their construction (although they were not of trussed-arch type). In 1956, ARDC erected a very large steel, trussed-arch weights-and-balances hangar of 360-foot clear span and 400-foot depth at Edwards, described in *Engineering News-Record* as directly derivative from the Idlewild hangars and assumed to be the work of Tedesko[25] (see Volume II, Chapter 3). By early 1958, working drawings for the prototype flight-test hangar at McClellan were "being completed in the field. These drawings are based on a new definitive design S-250 which supercedes the old double cantilever hangar design." The Air Force Directorate of Installations (civil

Plate 138: Radome Test Facility (Buildings 662 and 667), McClellan Air Force Base, 1956. Undated view. Courtesy of the History Office, McClellan Air Force Base.

improvised system during the late 1960s, using seven AN/FSS-7 radars as tracking sites.[34] The SLBM program evolved into PAVE PAWS during 1975-1987. The SMAMA acquired the system support mission for the first operational large phased-array radar, the AN/FPS-85 at Eglin Air Force Base, in 1969 (see Volume I, Part IV).[35]

With the exception of the B-36 mission during the early 1950s and that of the B-47 at the decade's close, the SMAMA's aircraft repair and modification work focused on fighters. Upon completion of the F-86 mission, Air Materiel Command assigned the base more complex fighter aircraft. The focused mission reflected a policy change within Air Materiel Command in mid-1957, whereby depots were no longer tasked by specific manufacturer (like Boeing, for example), but by type of aircraft or missile. In mid-1959, McClellan received work on the F-106, although the San Antonio AMA at Kelly retained the F-106 weapons system management function. Among its F-106 projects, the SMAMA handled updating the fighter aircraft's electronic radar guidance and tracking system linked to SAGE[36]—yet another illustration of McClellan's substantial involvement in air defense missions throughout the Cold War. At the start of the 1960s, the base had an upgraded runway, lengthened to 11,600 feet[37] (Plate 139). Fighter aircraft added to the McClellan workload included the F-100 and F-104, with both in repair and modification at the installation through the decade. The SMAMA also prepared F-100s for transfer to foreign governments through the Military Assistance Program beginning in 1966. McClellan pilots flight tested the refurbished aircraft before shipment (in a continued use of the flight-test hangar on the western edge of the base). During the second half of the decade, the SMAMA added the F-105. McClellan personnel were responsible for equipping the fighter with missiles to shoot down surface-to-air (SAM) missiles in Vietnam (the Wild Weasel program).[38]

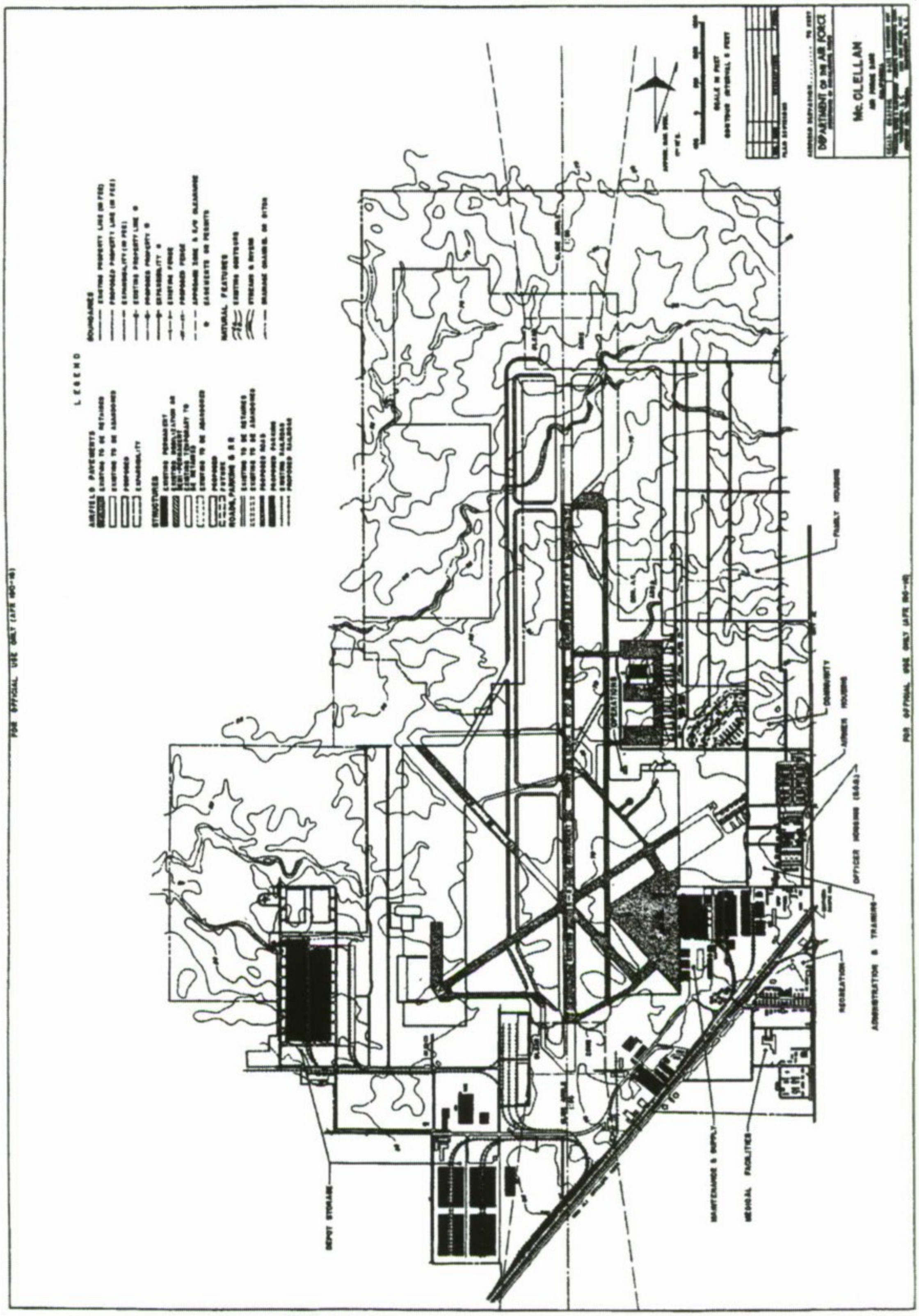

Plate 139: Directorate of Installations, Headquarters United States Air Force. Master Plan of McClellan Air Force Base, October 1957. Collection of K.J. Weitze.

In addition to increased fighter aircraft and ground radar repair, maintenance, and modification missions, McClellan supported the space program as of the early 1960s. The base would become the primary support for the Air Force Discoverer, Satellite and Missile Observation System (SAMOS), and Missile Detection Alarm System (MIDAS) satellite programs (see Volume II, Chapter 9). AFLC (the follow-on to Air Materiel Command) designated the SMAMA as the storage location for the Agena space vehicle. To accommodate maintenance of telemetry and guidance components before satellite launch, the SMAMA provided a mobile depot team to Vandenberg Air Force Base in Southern California. McClellan's involvement in a space support mission continued into the 1970s and afterwards, with receipt of a system management assignment for the Space Shuttle in late 1974. Space Shuttle efforts linked McClellan to both the Space and Missile Systems Organization (SAMSO) (at Los Angeles Air Force Station) and NASA.[39]

The 1960s also led to SMAMA's logistical support of the war effort in Vietnam. Early in the war, the Air Force deployed men to Vietnam with reactivated older aircraft, including the T-28 and the Navy's AD-5 (renamed the A-1E for the Air Force).[40] AFLC assigned McClellan the mission of overhauling the T-28 and made the depot the system support manager for the A (attack) -1E.[41] The SMAMA developed a program to send maintenance teams from McClellan to Vietnam to repair battle-damaged and crashed aircraft on site. The mobile maintenance team project, named RAM, was underway in 1965. Not surprisingly, the SMAMA established a parallel program for supply to American troops in Vietnam—RASS, a rapid-supply tasking for the war. RASS teams deployed to set up bases and worked in Vietnam to establish accounting, inventory, storage, and issue activities. Project Bitterwine was a related AFLC effort across its depots to move all the needed supplies and equipment for new installations in Southeast Asia. Bitterwine supported the Bare Base concept of Tactical Air Command (TAC), relying heavily on prefabricated infrastructure and packaged components for everything from buildings to aircraft (see Volume II, Chapter 4). For example, McClellan shipped all the materiel for setting up an air base at Tuy Hoa in late 1965. SMAMA personnel moved 5,000 tons of cargo from McClellan to the Port of Sacramento for sea shipment to Vietnam.[42] Similar large-scale supply and support efforts were underway from other AFLC depots (see Volume II, Chapter 6). McClellan served as a war materiel storage (WRM) location for prefabricated steel revetments, steel liners for aircraft shelters (the Concrete Sky program) (see Volume II, Chapters 4, 6, and 8), and 100-man hospitals (see Volume II, Chapter 2).[43] In yet another type of effort at Bien Hoa Air Base, the SMAMA assisted the logistics needs of the Vietnamese Air Force, including civil engineering guidance in establishing its maintenance shops. In 1964 and 1965, McClellan expanded its two large warehouses of the middle 1950s to meet the increased demands of supply to Vietnam.[44]

Two of McClellan's most significant aircraft repair programs were those for the F-111 and the A-10, missions that were acquired at the base in 1968 and 1977, respectively. The F-111 was initially tied to the war in Vietnam as an essential aircraft required by TAC. AFLC assigned the SMAMA the responsibility for the F-111 during its earliest development stages in 1962. The F-111 was an all-weather, swept-wing medium fighter-bomber, equipped with terrain avoidance radar that allowed the F-111 to fly over uneven surfaces at low altitudes. In spring 1968, TAC deployed the F-111 to Vietnam. The program of overhaul, repair, and modification began at McClellan immediately thereafter. As a key TAC asset throughout the Vietnam War, the F-111 required work at McClellan ranging from an upgrading of its radar systems and repair of its delicate electronics, to inspection for cracks and camouflage painting. The high humidity in Southeast Asia routinely damaged the aircraft. McClellan personnel worked on the F-111 series, beginning with the F-111A and ending the Cold War with the EF-111, an electronic countermeasure aircraft. McClellan modified and inspected 2,258 F-111s during a 30-year period. The base did not complete the F-111 mission until the late 1990s. For the A-10, AFLC also assigned the SMAMA as system manager for the aircraft. McClellan acquired the mission during the A-10's conceptual, design, and acquisition stages (for the A-X [attack

experimental]) and continued forward through maintenance, repair, and modification of the aircraft. TAC deployed this fighter to Europe and the Middle East.[45]

The length, urgency, and complexity of the F-111 program at McClellan offers a good case study of the types of buildings and structures needed to sustain the analysis, repair, and modification missions of the later Cold War decades. While base personnel continued to conduct many required tasks in the Airplane Repair Building of the late 1930s (Building 251) (see Plate 131), other specialty structures also became important. In April 1968, immediately after the first F-111 had arrived at McClellan, base civil engineering initiated design and construction for a new state-of-the-art paint hangar. Completed in 1969 at a cost of $1.7 million, the hangar (Building 692) featured a clear span of 202 feet and was 143 feet deep. Side shops and offices augmented the structure (Plate 140).[46] Environmental controls and ventilation were particularly noteworthy aspects of the hangar's design. Of interest, the firm responsible for the hangar, Leo A. Daly of Omaha,[47] was best known for its SAC alert moleholes and underground command posts at Offutt Air Force Base in Nebraska (see Volume I, Part IV), as well as for infrastructure for the Minuteman intercontinental ballistic missile (ICBM) and the third-generation hardened aircraft shelter (see Volume II, Chapters 4 and 6). Modern paint hangars and corrosion control facilities dated to at least the middle 1950s. The best example of a state-of-the-art paint hangar from that period was a precast, prestressed reinforced concrete hangar of 130-foot span erected at Hill (see Volume II, Plate 77). The hangar at Hill cost $2.25 million and featured an attached 28,000 square feet of shops. In 1960-1962, AFLC had also sponsored a program of prefabricated corrosion control facilities. Corrosion control shelters were essentially nose docks. At Robins Air Force Base in Georgia, the Air Force adapted a corrosion control shelter in 1964 as a cleaning and paint hangar for a single large aircraft (see Volume II, Chapter 11). Robins had first planned for a new paint hangar, but instead fell back to a cost-effective compromise. A similar example exists at Kelly in San Antonio. At that depot, AFLC modified a hangar from World War II as a paint hangar for the C-5 in 1972 (see Volume II, Plate 103). The paint hangar at McClellan in 1968 appears to be a singular example of a "new" structure constructed in a time of austerity.[48]

The paint hangar designed by Leo A. Daly for McClellan still presented a relative economy of construction as compared to the earlier effort at Hill (designed by Roberts & Schaefer). McClellan's hangar (Building 692) relied on the prefabricated trussed-arch for its basic structural framework. Leo A. Daly later collaborated with Butler Manufacturing in Kansas City for the design of an aircraft museum for SAC in the middle 1990s. A similar partnership may be present in the design of the paint hangar at McClellan. Butler Manufacturing was responsible for hangar or aircraft shelter designs in many instances during the years after 1958—in all cases, working with an architectural-engineering firm. Butler prefabricated shelters were prominent for TAC in particular and served as the basis of much of its flightline infrastructure in the 1960s and 1970s.[49] McClellan added numbers of generic prefabricated shelters and support buildings during the 1970s. In 1972, the installation erected seven prefabricated rigid-frame shelters along a taxiway near the flight-test hangar,[50] continuing to augment taxiways with more shelters as time went forward (see Plate 140). At about the same time as erection of the paint hangar, McClellan also built a small cold-proof facility to test F-111 wings for cracks. The cold-proof facility (Building 385) used prefabricated steel infrastructure as the basis for a sophisticated test shop able to simulate the temperatures of high altitudes (see Plate 132). On its interior, liquid nitrogen reduced the temperature to –45 degrees Fahrenheit. Hydraulic rams moved the wings of the F-111 up and down, while monitoring equipment detected the presence or absence of cracks requiring repair.[51] Although unconfirmed, the contributing prefabricator for the late 1960s paint hangar, F-111 shelters, and the cold-proof facility at McClellan is likely Butler Manufacturing.

The most sophisticated facility built at McClellan to assist personnel in aircraft analysis and repair was the Nuclear Radiation Center (also known as the McClellan Nuclear Radiation Center [MNRC])

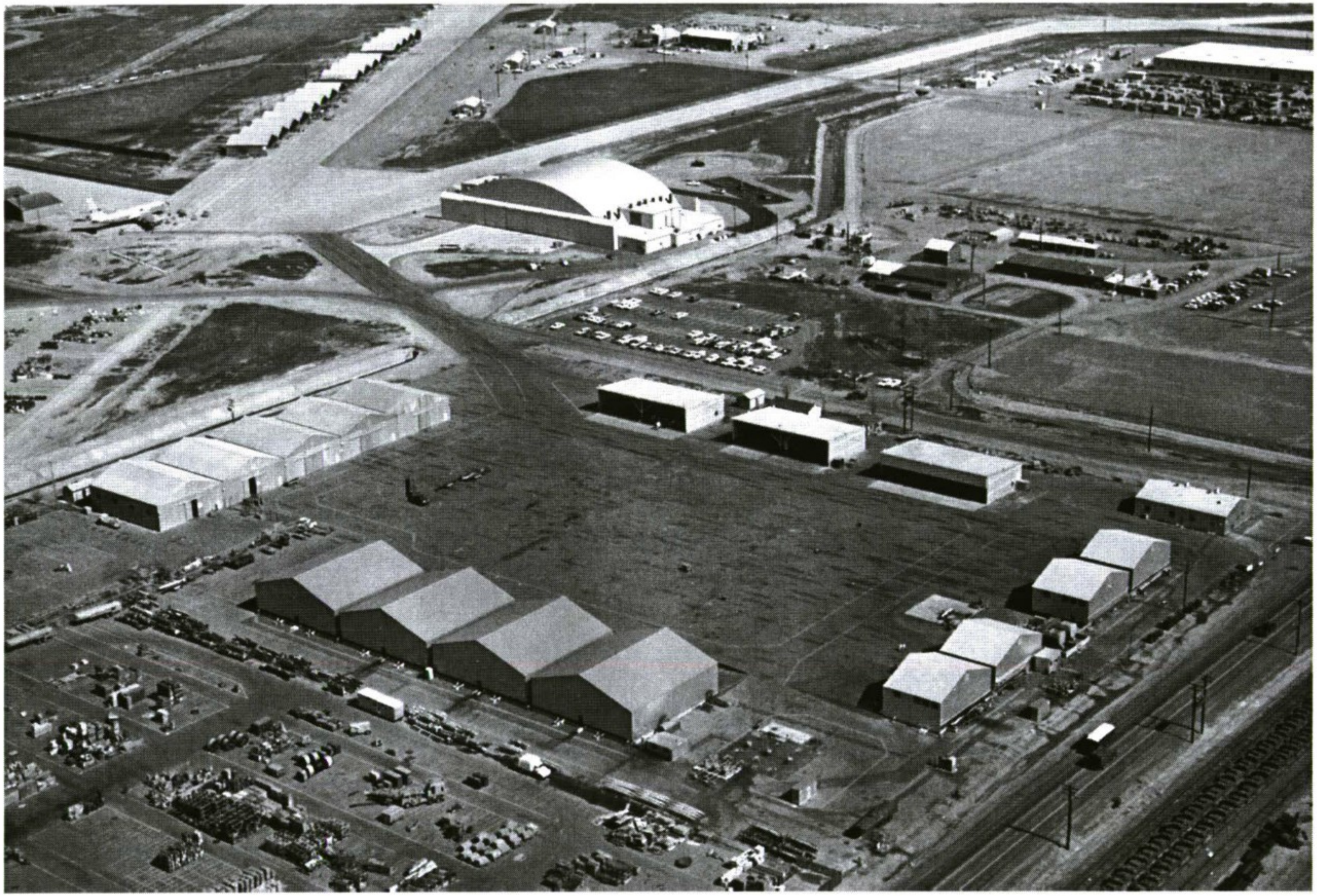

Plate 140: **Aerial View of McClellan Air Force Base, undated. Background, center: Leo A. Daly (and Butler Manufacturing, attributed), Paint Hangar for the F-111 (Building 692), 1968-1969. Middleground and background left: Prefabricated maintenance buildings and aircraft shelters. Courtesy of the History Office, McClellan Air Force Base.**

of the late 1980s. The AFLC project consisted of two structures and was under construction in mid-1985. The first structure, Building 248, featured a two-bay hangar with x-ray and neutron-ray robotic equipment (Plate 141). The Air Force adapted the neutron radiography from existing medical technology. AFLC titled the x-ray and neutron-ray hangar bays as the Maneuverable X-Ray Radiography System (MXRS) and the Maneuverable Neutron Radiography System (MNRS). Erected between 1985 and 1987, the test facility operated like a CAT (Computerized Axial Tomography) scan. Its robotic and imaging systems assisted in the detection of moisture and corrosion problems. Through use of the nondestructive inspection (NDI) radiographic bays, personnel could scan and analyze the wing of an F-111 in five hours, with detailed, highly accurate results. A full F-111 inspection that previously had taken a month or more was made possible in 36 hours. The x-ray scanning searched out the larger cracks. The neutron-scanning identified small cracks not visible through the x-ray process, as well as finding corrosion (termed "cancer" by the mechanics working on the aircraft). The radiographic procedures also ferreted out other structural flaws not visible to the eye, such as voids, instances where bonding was failing, and fire damage. The neutron bombardment, in particular, assisted mechanics in the repair of advanced tactical fighter aircraft assembled from composite materials.[52] The second structure, Building 258, was erected between 1986 and 1990. The Air Force first called this facility the Stationary Neutron Radiography System (SNRS). The equipment in Building 258 provided additional NDI radiographic capabilities and featured a General Atomics TRIGA (Training, Research, Isotopes, General Atomics) nuclear reactor at its center. Around the reactor were four bays of varied size that were capable of handling objects 12 feet wide, 34 feet long, and weighing up to 5,000 pounds.[53] Shuttered lenses channeled neutron bombardment from the reactor to each of the radiographic bays (Plate 142). Operational in January 1990, Building 258 represented maintenance technologies at the end of the Cold War, although its TRIGA reactor was an achievement long-proven and dated to the late 1950s. The facility at McClellan (Buildings 248 and 258) was one-of-a-kind within the Department of Defense, a $13 million investment by AFLC intended for use by TAC and the tactical arms of other military agencies for significantly improved inspection of their aircraft (such as the Navy's F-14).[54] Like other unique testing facilities at AFLC and AFSC bases, the MNRC was also available to other government agencies and industrial customers "to examine items ranging from rice plants to helicopter rotors."[55]

Air Materiel Command had used x-ray inspection in a limited way at the McClellan depot as early as its opening in 1939, expanding such inspections throughout the Cold War. Personnel undertook x-ray inspection during World War II entirely within a laboratory setting and, of necessity, coupled the NDI with other methods of analysis. Methods of aircraft inspection during the first 20 years of the Cold War remained focused away from x-ray analysis until the heightened needs of TAC during the Vietnam War stimulated new developments. In 1968, the SMAMA erected two tent hangars to the near southwest of the Airplane Repair Building adjacent to its cold-proof facility (see Plate 132). Again, the hangars were a truly interesting *ad hoc* test complex that substantially relied on prefabricated components. Steel revetments filled with four feet of sand provided a barricade from radiation. Sheathing for the hangars was sailcloth, made by a San Francisco sailmaker. Personnel towed aircraft into the larger tent hangar and placed components in the neighboring smaller tent. Men and women tested the F-111, F-100, F-105, and F-106 in the tent hangars, using these facilities for NDI until dismantlement of the tents in 1974 at the end of the Vietnam War. Yet another *ad hoc* solution for x-ray testing followed, with the adaptation of an existing standard nose dock (Building 240) sited immediately in front of the center bay of the Airplane Repair Building. Present on its site from the 1950s, the dock was prefabricated, bolted to its concrete apron. In the middle 1970s, personnel lined its walls with approximately 96 tons of protective lead sheets, nicknaming the nose dock the "lead shed." Designed to accommodate the nose and wings of a large bomber, the nose dock could fit an entire fighter aircraft within its walls—here adapted as an x-ray NDI test facility. The SMAMA used the lead shed in conjunction with x-ray laboratories set up in several bays of adjacent

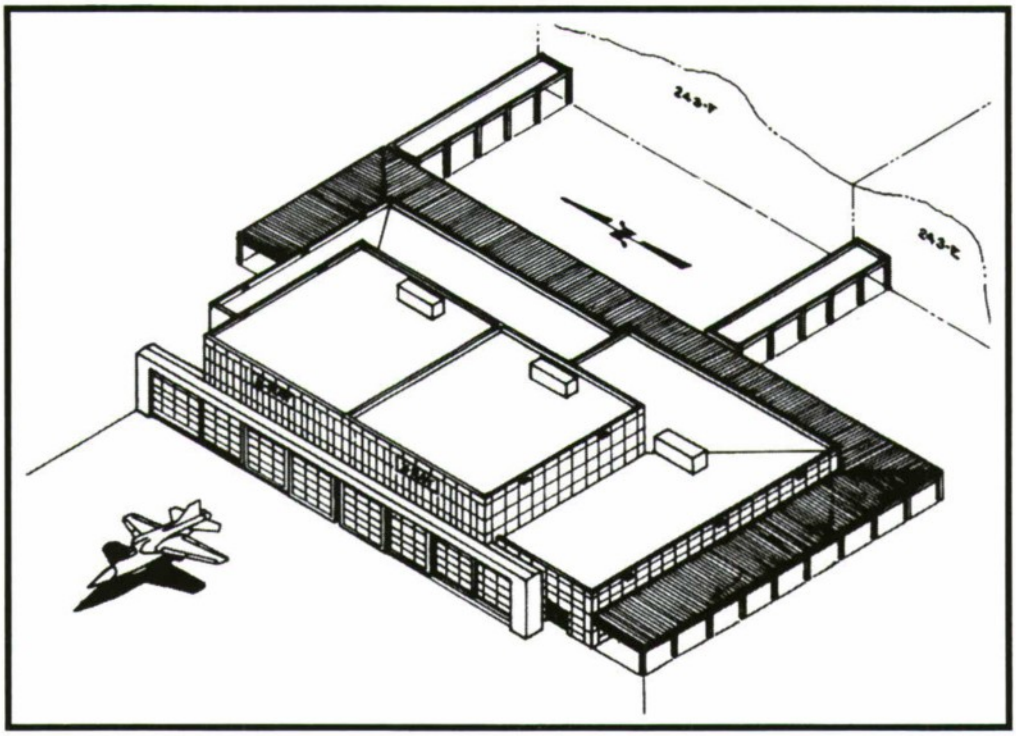

Plate 141: Two-Bay Hangar (Building 248) for Maneuverable Neutron and Maneuverable X-Ray Radiography, Nuclear Radiation Center, McClellan Air Force Base, 1985-1987. Courtesy of the History Office, McClellan Air Force Base.

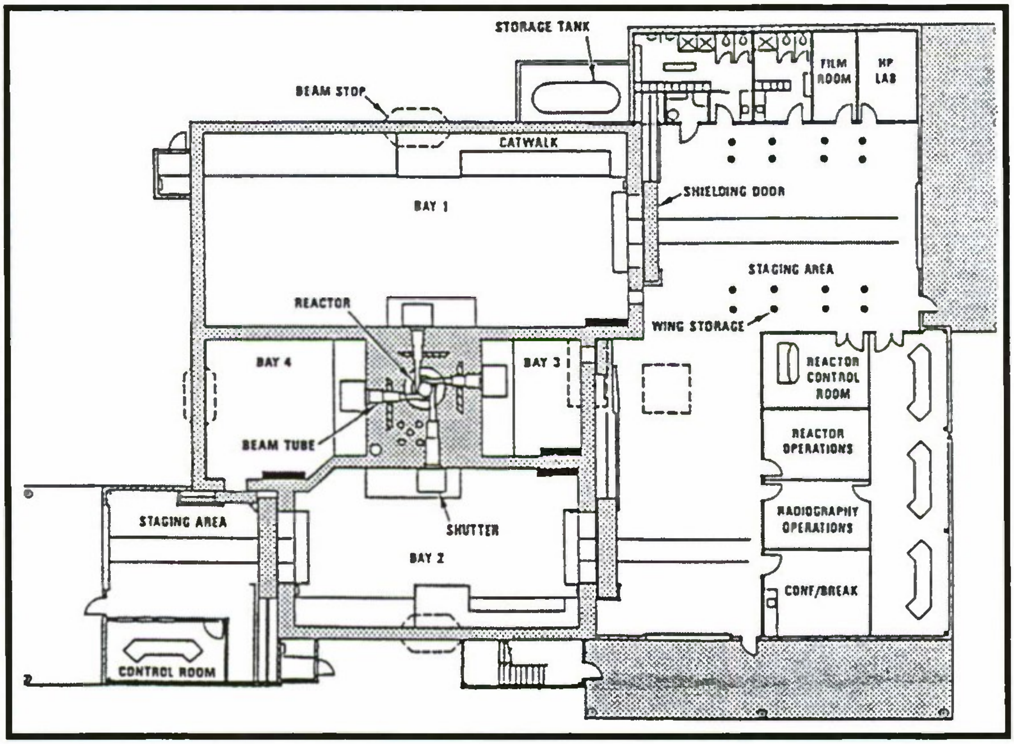

Plate 142: Stationary Neutron Radiography System (Building 258), Nuclear Radiation Center, McClellan Air Force Base, 1986-1990. Courtesy of the History Office, McClellan Air Force Base.

Building 243, to the near north of the Airplane Repair Building.[56] The MNRC replaced the makeshift NDI facilities that personnel had used at McClellan during most of the Cold War. With base closure in 2001, the Air Force transferred the MNRC to the University of California at Davis for its continued use as a high-technology test complex.[57]

Key Associated Architects and Engineers

Architects and engineers of major significance who designed buildings and structures for the Air Force at McClellan Air Force Base during the Cold War included firms discussed in Volume I, or in other chapters of Volume II, as noted:

- Ammann & Whitney, of New York (Volume I, Part II);
- Leo A. Daly, of Omaha (Volume II, Chapter 4);
- L.P. Kooken, of Baltimore (Volume I, Part II);
- Kuljian Corporation, of Philadelphia (Volume II, Chapter 3); and,
- Roberts & Schaefer, of Chicago (Volume II, Chapter 6).

Also key at McClellan is the presence of prefabricated aircraft shelters and hangars, from World War II through the end of the Cold War. Butler of Kansas City is the most prominent manufacturer represented on base.

---

[1] The reader can trace the broad patterns of lineage for the installation in Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). The McClellan chapter includes the sequence of installation names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base.
[2] Maurice A. Miller (ed.), *McClellan Air Force Base 1936-1982* (McClellan Air Force Base: Sacramento Air Logistics Center, Office of History, December 1982). Although general in its discussion of McClellan, the study offers a framework for the history of the installation and serves as a basis for the chronology presented here. *McClellan Air Force Base 1936-1982* does contain a significant number of errors and should be used in addition to other sources.
[3] The Air Corps Board, Maxwell Field, *Report on Plan for Underground Aviation Facilities*, 9 January 1936.
[4] Miller, *McClellan Air Force Base 1936-1982*, 1982, 9-17.
[5] "Building Bases for Our Air Forces," *Engineering News-Record* 125, 17 (24 October 1940): 50-61. Includes specific discussion of McClellan, with photographs. Also see historic building inventory forms of 1988 in Jones & Stokes Associates, Inc., *Cultural Resources Management Plan for McClellan Air Force Base* (Sacramento: Jones & Stokes Associates, Inc.: 31 January 1997). J. Cunningham and M. Maniery completed the forms for PAR & Associates, Sacramento, in a separate effort predating preparation of the Cultural Resources Management Plan.
[6] Historic inventory form for Building 360 in Jones & Stokes Associates, Inc., *Cultural Resources Management Plan for McClellan Air Force Base*, 1997. Stephen D. Mikesell prepared the form through JRP Historical Consulting, Davis, California, in 1995.
[7] Miller, *McClellan Air Force Base 1936-1982*, 1982, 41-59.
[8] *Ibid*, 61. The date of Crossroads involvement by McClellan is incorrectly printed as January 1945.
[9] *Ibid*, 61-63.
[10] Kistner, Wright & Wright, Los Angeles, "McClellan Air Force Base. Technical Laboratory Building," drawing E-103-30-4, 14 September 1955; and, Franceschi & Dreyfuss, and, Rickey & Brooks, Sacramento: "Special Projects Laboratory Addition FY1957," drawing 35-06002, 14 January 1957, and, "Special Projects Laboratory Addition," 15 May 1959.
[11] Headquarters United States Air Force, *History of the Assistant Chief of Staff, Installations 1 July – 31 December 1956*, 40.

---

[12] Headquarters United States Air Force, *History of the Directorate of Installations 1 July – 31 December 1957*, 42.
[13] Miller, *McClellan Air Force Base 1936-1982*, 1982, 67-70.
[14] Lenore Fine and Jesse A. Remington, *The Corps of Engineers: Construction in the United States*, volume in *United States Army in World War II: The Technical Series* (Washington, D.C.: Office of the Chief of Military History, 1972), 623.
[15] Kuljian Corporation, "Hangar Maintenance Double Cantilever Medium Bomber A/C (Expanded) (No Future Expansion)," drawing 39-01-02, stamped date 7 January 1954.
[16] Charles Goodman Associates, "Nose Docks for the C-74 and C-124," drawing 39-05-05, 19 June 1952.
[17] "Sacramento Air Materiel Area, Miscellaneous Buildings, A.D.C. Interim Facilities," multiple drawings, 11 May 1954 and 7 January 1955.
[18] Holabird, Root & Burgee, with Farm-Rite Implement Company, Chicago, "Aircraft Service Docks Types MB1A, MB2A, MB6A, MB7A, MB8, MB11," multiple drawings, June and November 1956.
[19] 552nd AEW&C Wing Information Office, "Air Defense and the 552nd AEW&C Wing," four-page typescript of 19 May 1972.
[20] Miller, *McClellan Air Force Base 1936-1982*, 1982, 77.
[21] *Ibid*, 78-81.
[22] Roberts & Schaefer (attributed, but unconfirmed), "Hangar, Flight Test," drawing AW 39-01-09, multiple drawings, earliest dates of October-December 1958.
[23] Headquarters United States Air Force, *History of the Assistant Chief of Staff, Installations 1 January – 30 June 1957*, 61.
[24] Marvin E. Warner and David P. Billington, "Precast Concrete Shows 21-Percent Saving on Air-Base Buildings," *Civil Engineering* 27, 4 (April 1957): 33-37.
[25] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., November 1999), 58-59; "Steel Trussed Arches Span 360 Ft in Hangar," *Engineering News-Record* 157, 6 (August 1956): 36-38.
[26] Headquarters United States Air Force, *History of the Directorate of Installations 1 January – 30 June 1958*, 72.
[27] Headquarters United States Air Force: *History of the Directorate of Installations 1 July – 31 December 1958*, 70, and, *History of the Directorate of Civil Engineering 1 January – 30 June 1959*, 41.
[28] "Precasting 35 Acres of Roof Panels for Warehouse," *Engineering News-Record* 158, 22 (30 May 1957): 42-43.
[29] Miller, *McClellan Air Force Base 1936-1982*, 1982, 83-84.
[30] "Radome Testing Facility," multiple drawings, 22 October 1956, and, "Shop, Radome Test Facility, Additions," multiple drawings, October 1968.
[31] "Electronic Test Facility Radar Depot," drawing 35-03-06, stamped date of 19 April 1967. "AN/FPS" is not actually an acronym, but can be broken down into components. The "AN" is a joint military designation for "Army-Navy," while "F" indicates "fixed;" "P" indicates "radar" (the type of electronic equipment); and, "S" indicates "detection."
[32] David F. Winkler, *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program* (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, for Air Combat Command, June 1997), 75-76.
[33] Miller, *McClellan Air Force Base 1936-1982*, 1982, 124.
[34] The AN/FSS-7 was a fixed (F) special piece of equipment (S) used for detection (S).
[35] Miller, *McClellan Air Force Base 1936-1982*, 1982, 125.
[36] *Ibid*, 81-82.
[37] *Ibid*, 126. Runway lengths and dates of lengthening are in conflict in the available sources. Maps of 1957 (as well as the requirements of the B-36) suggest an early-to-middle 1950s expansion to 10,300 feet (from the World War II length of 7,000 feet), with the lengthening to 11,600 feet dating to 1959-1961.
[38] Miller, *McClellan Air Force Base 1936-1982*, 1982, 98-100.
[39] *Ibid*, 92-93, 125.
[40] The "AD" references the "A" for "attack" or "amphibian" in Air Force and Navy aircraft designations, and the "D" for the plane's manufacturer, Douglas Aircraft.
[41] Miller, *McClellan Air Force Base 1936-1982*, 1982, 95-96.
[42] *Ibid*, 106-115.

---

[43] Headquarters United States Air Force: *History of the Directorate of Civil Engineering 1 July – 31 December 1968*, 7; *History of the Directorate of Civil Engineering 1 July – 31 December 1970*, 118.
[44] *History of the Directorate of Civil Engineering 1 July – 31 December 1970*, 118-120.
[45] *Ibid*, 101-105, 122; "History of the F-111," one-page typescript provided by the History Office, McClellan Air Force Base, ca.1998.
[46] Miller, *McClellan Air Force Base 1936-1982*, 1982, 132
[47] Leo A. Daly Company, "Aircraft Paint Facility," drawing AW 35-28-06, stamped date of 30 April 1968.
[48] "Hangars by Roberts and Schaefer Co. Chicago New York, " two black binders of company jobs, with photographs and drawings, ca.1956. In the Anton Tedesko collection, Department of Civil Engineering, Princeton University.
[49] Karen J. Weitze, *Cold War Infrastructure for Air Defense: The Fighter and Command Missions* (Sacramento: KEA Environmental, Inc., November 1999), 54.
[50] Miller, *McClellan Air Force Base 1936-1982*, 1982, 133.
[51] *Ibid*, 143.
[52] Douglas Baldwin, "Robots in the Hangar," *Air & Space Smithsonian* 3, 6 (February / March 1989).
[53] SSgt Charles Irwin, *Base Closure and the McClellan Nuclear Radiation Center*, interview with Dr. Wade Richards, Chief of Nuclear Licensing and Operations, Sacramento Air Logistics Center, Sacramento Air Logistics Oral History Interview #16, Air Force Materiel Command, October 1999.
[54] *Ibid*; "Ribbon Cutting Ceremony on the SNRS PRAM Project," Executive Summary, Staff Summary Sheet, 29 November 1989, in File "25-4-1 X-ray Inspection," History Office, McClellan Air Force Base. Location after base closure, unknown.
[55] Irwin, *Base Closure and the McClellan Nuclear Radiation Center*, Interview with Dr. Wade Richards, October 1999.
[56] Sacramento Air Logistics Center, *Technology Profile NDI*, SM-ALC-MCAFBP 66-38, 1 April 1985.
[57] Irwin, *Base Closure and the McClellan Nuclear Radiation Center*, Interview with Dr. Wade Richards, October 1999.

Chapter 11: Robins Air Force Base

Historic Missions of the Cold War

Robins Air Force Base was a key depot of Air Materiel Command (and subsequently, Air Force Logistics Command [AFLC]) during the Cold War, active in this role from its origins as a logistics installation during early World War II into the present. Responsible for the Warner Robins Air Materiel Area (AMA) (and after 1974, the Warner Robins Air Logistics Center [ALC]), the base sustained a range of command assignments. Between 1945 and 1950, before the formal onset of the Korean War, activities at Robins concentrated on cocooning B (bomber) -29s and shipping aircraft parts to Europe. Cocooning of the B-29s was the first distinctively Cold War project to arrive at the installation: the project prepared the bombers for restoration on short notice if the need arose to go to war. As of Korea, however, Air Materiel Command began to shape the base for its Cold War overhaul, maintenance, and supply missions. Tasking in the early 1950s was still mixed, with important continued work on the B-29, as well as repair for the F (fighter) -86. The second Cold War project to arrive at the installation was modification and shipment of the Matador, a tactical missile in the form of a pilotless aircraft. Air Materiel Command augmented infrastructure at Robins during the 1950s. Engineers lengthened runways twice, at mid-decade and again in preparation for a Strategic Air Command (SAC) alert wing of 1958. The Air Force also erected new warehouses on base, important to all Air Materiel Command / AFLC installations. Robins served as a shipping facility to both Europe and Asia, and as such received one of the largest pair of Special AMC (Air Materiel Command) Warehouses built for the command. Construction at Robins was among the earliest for the 20 clusters of Special AMC Warehouses in the continental United States. The Special AMC Warehouse was a high-profile commission within the engineering community and one that faced unusual challenges related to its cutting-edge technology. The warehouse pair at Robins functioned as a case study across Air Materiel Command for improvements to the structure during the middle 1950s, following a partial collapse of a sister warehouse at the Shelby Air Force Depot at Wilkins Air Force Station in Ohio (see Volume I, Plates 32-33).

During the 1960s, Air Materiel Command / AFLC assignments at Robins became increasingly sophisticated. The installation hosted two prototype structures for the Air Force: a fuel systems nose dock of 1961 and a paint hangar of 1963-1964. Major missions over time included ones for the B-57, the Matador and Mace, and progressive cargo transport aircraft. During the Vietnam War, Robins served as a storage location for prefabricated structures' components, paralleling this function at selected other AFLC depots. Late in the war Robins would store and ship the Hayman igloo, a demountable igloo of the middle 1980s. In the middle 1970s, a new major mission arrived at the Warner Robins ALC, that for the F-15. At the end of the Vietnam War, the installation hosted a large phased-array radar for the Perimeter Acquisition Vehicle Entry Phased Array Radar System (PAVE PAWS), one of four such radars built as a warning network to monitor the possible firing of sea-launched ballistic missiles (SLBMs) (and one of 10 American large phased-array radars in 1999).

Primary Missions

Designated as responsible for the Warner Robins AMA (WRAMA), Robins Air Force Base supported logistics missions of Air Materiel Command / AFLC, including:

- cocooning, refurbishment, and maintenance of the B-29;
- selected assignments for the F-86K, a version of the fighter prepared for deployment in Europe;
- case study analysis for the Special AMC Warehouse;
- prime responsibility for the B-57, with major deployment of the fighter-bomber overseas;

- prime responsibility for the Matador and the Mace tactical missiles during the 1950s and 1960s, with deployment in Germany and Japan;
- prime responsibility for multiple cargo transport aircraft, beginning in the middle 1950s;
- maintenance and overhaul responsibilities for Air Force helicopters;
- responsibility for prefabricated structures shipped overseas, notably during the Vietnam War and again after the middle 1980s to Europe; and,
- prime responsibility for the F-15 as of the middle 1970s.

Tenant Organization Missions

Notable tenant missions at Robins included those of SAC and Air Force Space Command (AFSPC):

- SAC alert during the late 1950s into the middle 1960s; and,
- a PAVE PAWS radar installation in 1986.

Chronology

Robins Air Force Base derives from the early and middle 1930s logistics planning of the Air Corps for regional materiel depots in the continental United States. The Wilcox-Wilson Bill, Public Law 263 of August 1935, stimulated the War Department to evaluate locations for the needed air depots. Selected construction for new air depots was underway the next year. As was uniformly true in other parts of the country, communities seeking to revitalize their economies from the effects of the Depression interpreted the War Department's buildup as an invitation to promote regional strengths and to lobby for a base in their areas. Macon, north of Robins, began this process at the outset of 1936. Local business leaders solidified community resolve in early 1940 when a group from Macon went to Washington, D.C., to offer cost-free sites to the federal government for the establishment of a military installation. The most immediate result was a civic donation to the War Department of 1,010 acres of land from the 1830s Henry Feagin plantation near Macon. Valued at just over $100,000, the Feagin plantation in Avondale provided the acreage required to lay out Cochran Field—an installation, again like many across the nation, set up for pilot training. In June 1941, the Army Air Corps opened Cochran Field (first known as Avondale Army Air Field) as a basic training facility for Army pilots, soon tiered within the Southeast Army Air Forces Training Center for basic, primary, and advanced pilot training. The Southeast Army Air Forces Training Center was also responsible for contract training of pilots for the British Royal Air Force (RAF).[1]

Planning for an Air Corps depot in the southeastern United States overlapped the development of Cochran Field. By the opening of 1941, a number of cities in the region desired the depot. Locations soon narrowed to the vicinities of Atlanta and Macon. Competition continued during the year. The Air Corps reviewed four sites near Macon, including one opposite the Air Corps Basic Flying Training School at Cochran Field and one at Wellston, where the depot would be located. Macon representatives offered the federal government approximately 3,000 acres of cost-free land. The War Department chose the Wellston site (eight miles south of Cochran Field) in mid-year. The federal government quickly negotiated agreements with local builders to construct needed area housing and with the Southern Railroad to support an increased volume of shipments on regional trackage. In August 1941, the Army unofficially named the future installation the Georgia Air Depot (and alternately, the Southeast Air Depot).[2] Construction of the depot during late 1941 into 1943 overlapped formal federal acceptance of land title. The Army did not receive legal title until mid-1943, even as the depot's major buildings had gone up. The Office of the United States Engineer supervised runway layouts and the erection of buildings at the Southeast Air Depot beginning in September 1941, setting up a base of operations at Cochran Field in Avondale. An immediate and

recurrent problem for construction of the air depot was the high water table, due to the proximity of the Ocmulgee Swamp.[3]

Infrastructure for the Southeast Air Depot featured standard runways and buildings for World War II materiel bases. Engineers planned the three 5,000- by 150-foot runways for extensions up to 7,500 feet, constructing each for weight loads appropriate to the B-17 or B-19. Square slabs of nine-inch thick reinforced concrete (known as flags) comprised the runways, while similar concrete flags of six-inch thickness defined the taxiways. Aprons were also reinforced concrete. Flag dimensions varied from seven- to six-foot square. Engineers built 86 hardstands at the airfield, relying on an eight-inch base of compacted soil finished with six inches of soil cement atop a tar primer and sand. From the outset, the Southeast Air Depot was geared toward heavy, large aircraft. The United States Engineer Office for the region hired the Atlanta firm of Robert & Company to handle the overall utilities for the installation and to oversee construction of the cantonment (primarily comprised of 700- and 800-series woodframe temporaries).[4] Individual hangars, as well as other structures typical for an air depot, next went in place.[5] These included a four-bay Airplane Repair Building (Building 125), an Operations – Transport Squadron and Flight Test Hangar (Building 110), and rail-accessed warehouses (Buildings 300-301) (Plate 143). The Airplane Repair Building was a steel maintenance hangar of late 1930s design through the Army Quartermaster Corps (Plate 144). The Army Air Corps planned this particular hangar to be large enough to accommodate the future B-29. The distinctive tied-arch hangar had a span of 275 feet, configured at the air depots as one to four hangar bays varying in depth from 190 to 200 feet. Base planners sometimes constructed engine repair shops to the rear (as at McClellan Field in Sacramento), but most often bracketed center shops by paired hangars as at Robins (see Volume II, Chapters 6, 7, 10, 12, 13, and 14). Also present at Robins was the Operations – Transport Squadron and Flight Test Hangar (see Plate 143). Originally designed by Detroit architect Albert Kahn as the Transport Squadron Hangar, the structure evolved as a doubled hangar, and finally—after modification by New York engineer Fred N. Severud during 1940-1941—to the Operations – Transport Squadron and Flight Test Hangar. The hangar was the immediate precursor to a noteworthy achievement by Severud for the first B-36 nose dock of 1944-1945 (see Volume I, Plate 5 and Volume II, Chapters 4, 6, 7, 12, 13 and 14).

The other key buildings common to an air depot were an armament repair shop and engine test cells (Buildings 158 and 181, respectively) (Plate 145). Cleveland architect J. Gordon Turnbull designed each of these structures. The Air Corps and Army Air Forces always erected the test cells as substantial reinforced concrete structures, while their rendering of the Armament, Fire Control, Supply and Repair Building varied from reinforced concrete to alternate masonry (see Volume II, Chapters 6, 7, 12 and 13). Air Materiel Command would choose Turnbull immediately after World War II to design an underground pilot plant. The 1946-1949 pilot plant was among the earliest proto-hardened construction projects of the Cold War (see Volume I, Part III). Holabird, Root & Burgee of Chicago received the supervisory contract for the construction of buildings at the Warner Robins Air Depot in 1943. The contract also included design responsibility for a variety of structures at the airfield. While the firm's role at Robins was routine, Holabird, Root & Burgee landed a major Air Force contract for a network of air defense command posts coordinated jointly through Headquarters Air Materiel Command and Headquarters Air Defense Command (ADC) in 1948-1949 (see Volume I, Parts III and IV).[6]

Several successions of name changes for the Southeast Air Depot occurred during World War II and in the late 1940s. In March 1942, the installation became the Wellston Air Depot, redesignated the Wellston Army Air Depot in September. Ironically, the nearby town of Wellston changed its name to Warner Robins just as the depot became the Wellston Army Air Depot in September. Lieutenant Colonel Charles E. Thomas, commander of the Southeast (Wellston) Air Depot from November 1941

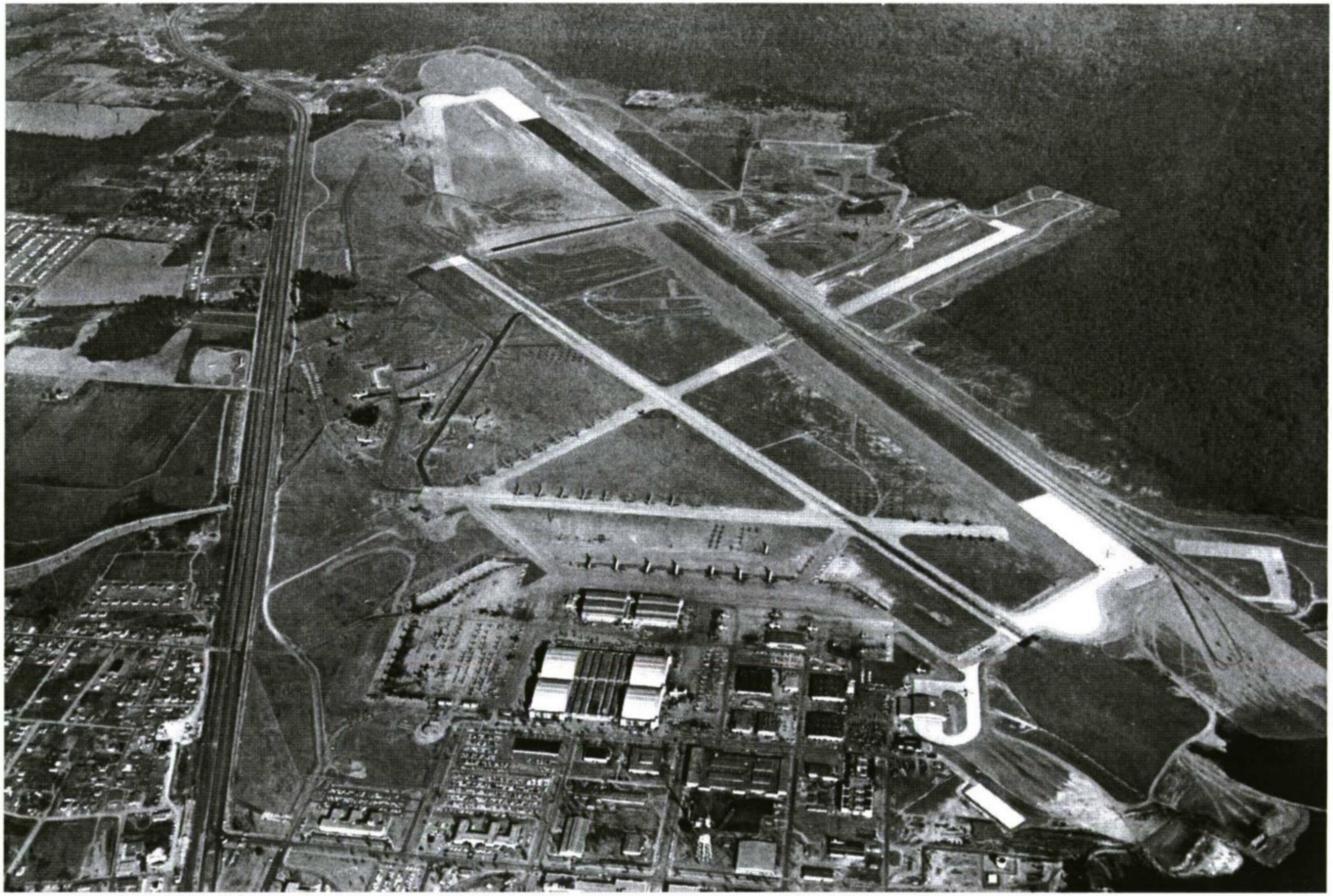

Plate 143: Aerial View of Robins Air Force Base, 31 December 1955. Foreground, center: Airplane Repair Building (Building 125) and the Operations - Transport Squadron and Flight Test Hangar (Building 110). Lower foreground, center: Armament, Fire Control, Supply and Repair Building (Building 158). Lower foreground, right: Engine Test Cells (Building 181). In *History of Warner Robins Air Materiel Area 1 July – 31 December 1955.*

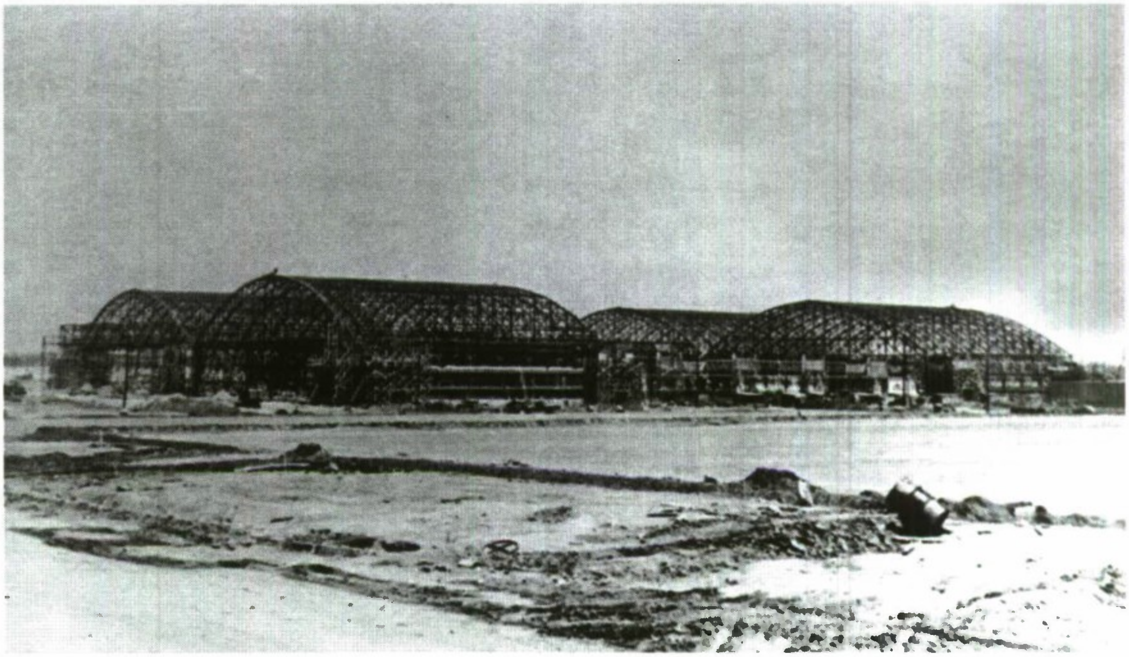

Plate 144: Airplane Repair Building (Building 125), Southeast Air Depot, Wellston, Georgia, 28 April 1942. Courtesy of the History Office, Robins Air Force Base.

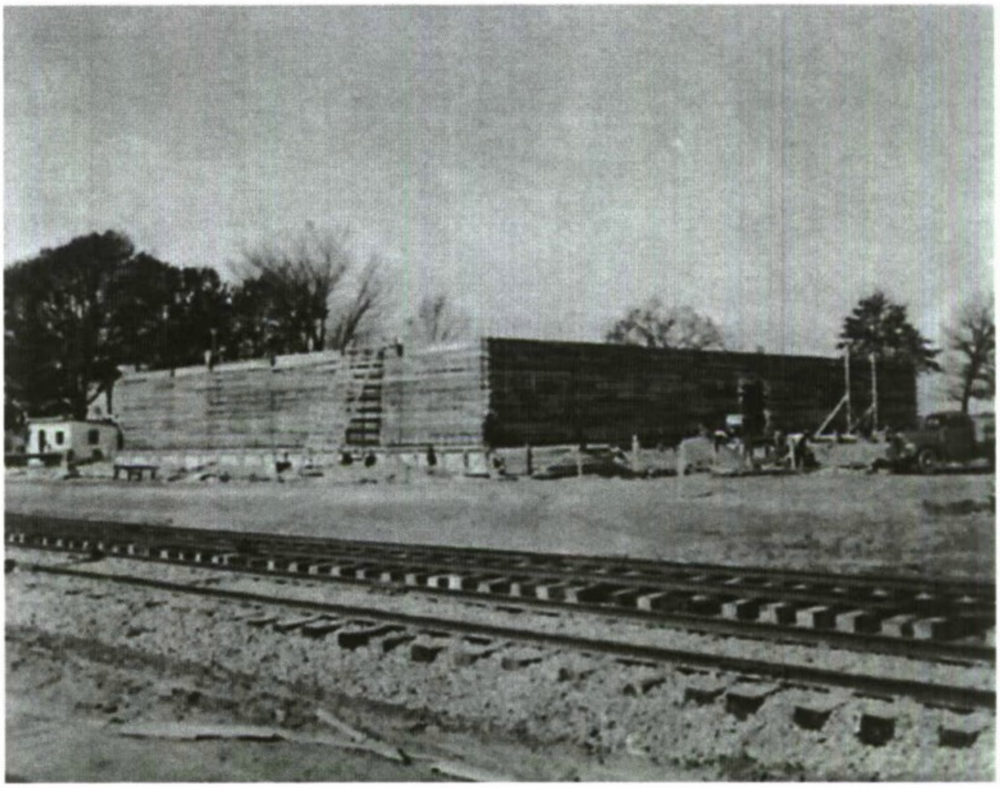

Plate 145: J. Gordon Turnbull. Armament, Fire Control, Supply and Repair Building (Building 158), Southeast Air Depot, Wellston, Georgia, January 1942. Courtesy of the History Office, Robins Air Force Base.

to June 1943, had convinced the townspeople to make the name change for their community. In mid-January 1942, the installation became Robins Field and in mid-October 1942, the Army renamed the depot as the Warner Robins Air Depot (and almost immediately, the Warner Robins Army Air Depot) in honor of the recently deceased Brigadier General Augustine Warner Robins. Brigadier General Robins had served as the Chief of the Materiel Division at Patterson Field in Dayton, Ohio, from 1935 to 1939, then becoming the commander for the Air Corps Training Center at Randolph Field in San Antonio until his death in June 1940.[7] In March 1943, the Warner Robins Army Air Depot became the regional headquarters for materiel storage and distribution within Air Service Command, responsible for several auxiliary airfields in the Southeast. The installation continued in this role as Air Service Command transitioned to Air Technical Service Command in May 1944 and to Air Materiel Command in 1946. Air Materiel Command designated the Warner Robins Air Materiel Area (WRAMA) in early 1946. Throughout 1942-1946, the installation name remained Robins Field. In January 1948, Robins Field became Robins Air Force Base. The WRAMA continued as the depot designation until the formation of the Warner Robins ALC in 1974 (see Volume I, Part II).[8]

During World War II, the Wellston (subsequently, Warner Robins) Army Air Depot trained Air Depot Groups (ADGs) for overseas duty in Europe and Asia, and for procedures appropriate to warehousing supplies. In mid-September 1942, Wellston Army Air Depot managed six subdepots: at Cochran, Moody, Turner, and Spence Fields in Georgia; at Shaw Field in South Carolina; and, at Tuskegee Field in Alabama. Before the close of the month, subdepots attached to Wellston rose to 23 due to transfers from the Mobile Army Air Depot to the west, with 18 additional air depot detachments also assigned. By 1944, the numbers of subdepots had climbed further. These installations were typically training airfields within the region. In support of the Southeast, the Wellston Army Air Depot handled supplies for trainer aircraft, while the Mobile Army Air Depot managed logistics for tactical aircraft. In April 1943, Air Service Command established distinct boundaries separating the Wellston and Mobile geographic areas. By late in the year, the two materiel areas became self-sufficient, with each handling both trainer and tactical aircraft spare parts. Between 1942 and the close of World War II, personnel at the Wellston (Warner Robins) Army Air Depot overhauled and modified about 2,000 planes. The workload included repair projects for more than 21,000 aircraft engines. Aircraft cycling to the base included A (attack) -20s, A-29s, B-17s, B-24s, B-25s, B-34s, and RP (reconnaissance pursuit) -40s. Among the engines were over 4,700 R-2800s, the engine of the B-29. Men and women at Wellston (Warner Robins) Army Air Depot also repaired and refurbished 488 Norden bombsights (in the Armament, Fire Control, Supply and Repair Building).[9] In 1945, true of all American depot installations, activities at Warner Robins Air Depot fell off. Air Technical Service Command completely curtailed procurement activities with the surrender of Japan in September.

At the outset of the Cold War during the spring of 1946, Air Materiel Command assigned Warner Robins Army Air Depot the task of preparing 268 B-29s for storage, as well as completing the overhaul of numbers of aircraft engines. At Robins Field, depot personnel "cocooned" the B-29s by removing their fuel and spraying the aircraft with three layers of yellow, blue, or silver rubberized protective plastic. Cocooning was a subset of "mothballing" in official Air Force terminology, but not all mothballing included cocooning.[10] Many mothballed planes were stored in the open without protective coating where a drier climate caused less corrosion. In 1946, the Army Air Forces airfields that filled this role were Davis-Monthan in Arizona, Garden City in western Kansas, Hobbs in New Mexico, Independence in western Missouri, Pyote and South Plains in West Texas, Hill in Utah, and Victorville (George Air Force Base) in Southern California (see Volume I, Part II). At the end of 1946, Robins also handled repair of airborne communications equipment, along with the AMAs for Sacramento (at McClellan) and San Antonio (at Kelly). Cocooning and storage of B-29s continued at Robins during 1947. The installation operated as one of Air Materiel Commands' AMAs, surviving

post-war consolidation from 11 AMAs in 1946 to seven in 1947 (Middletown, Warner Robins, Mobile, San Antonio, Oklahoma City, Ogden, and Sacramento). One of the first depots absorbed by others post-World War II had been the Miami jurisdiction—absorbed by the Warner Robins AMA (see Volume I, Plates 10 and 28). During 1948-1949, Air Materiel Command began to adopt business and manufacturing practices applicable to automated supply warehousing, with service testing by the Mobile AMA. (General Robins, for whom Robins Field / Air Force Base was named, had devised a system of cataloging supplies in the Air Corps that continued to be used throughout the Cold War.[11]) By late 1949, the command had moved to a two-zone system for the continental United States, with the Warner Robins AMA subsumed within the eastern zone complementing its Middletown (Pennsylvania) and Mobile (Alabama) counterparts. During June 1948 through September 1949 too, the Warner Robins AMA participated in airlifting supplies to Berlin, in response to the blockade of West Berlin by the government of the Soviet Union.

In the early 1950s, Robins began to define itself more distinctly as a Cold War depot for Air Materiel Command (and after 1961, for AFLC). AMAs nationwide had re-expanded to eight, with the reactivation of the San Bernardino AMA in Southern California (Norton Air Force Base). As events deteriorated in Korea in late May 1950, Air Materiel Command responded with immediate orders to Robins to reclaim the cocooned B-29s at the base for anticipated service needs. Each of the Air Materiel Command depots began refurbishment of World War II bombers, including B-25s, B-26s, B-29s, and B-50s (modified B-29s). Robins and Kelly Air Force Bases prepared 72 B-29s for shipment to Great Britain. The Korean War was formally underway in late June. By May 1951, a production line for B-29 repair was in place at Robins. The key hangar remained the four-bay Airplane Repair Building (Building 125) of a decade earlier. Doorways of the Airplane Repair Building were 250 feet wide by 37 feet tall, intended to accommodate the even greater tail height of future heavy bombers through a center lift door of 15 feet square. In April 1951, the first distinctive Cold War mission arrived at Robins: the Matador tactical missile.[12] Each of Air Materiel Command's depots received both aircraft and missiles assignments during the 1950s, with missile modification and repair missions becoming much more defined late in the decade. The Matador, developed by the Glenn L. Martin Aircraft Company of Baltimore, was the earliest Air Force missile planned for biological and chemical warheads. In February 1948, the Air Force formalized intentions for incendiary, biological, and chemical warheads for the Matador. For these efforts, the research and development (R&D) of the warheads was the responsibility of the Army Chemical Center at the Edgewood Arsenal (also in Maryland). Specific Matador projects for biological and chemical warheads were underway during 1950-1951. Drop testing of Matador warheads (nose cones) became the responsibility of the Holloman Air Development Center adjacent to the Army's White Sands Proving Ground (later, Missile Range) in New Mexico, where V (Vergeltung / Vengeance) -2 experiments had gone forward in the late 1940s. Holloman functioned as the guided missiles development installation for Air Research and Development Command (ARDC), with next-phase Matador launches at the command's Missile Test Center at Patrick Air Force Base in Florida. Testing for the Matador, a pilotless aircraft (the MX [missile experiment] -771, and as produced, the B-61), accelerated in 1952. As of this date, the Air Force focused on developing a sarin gas (GB) warhead. Problems tied to a fin-stabilized GB warhead for the Matador led to meetings at the Wright Air Development Center at Wright-Patterson Air Force Base in Ohio in early 1954. The Matador had entered operational Air Force inventory before the meetings, with a conventional explosive warhead. (ARDC cancelled the Matador chemical warhead program in December 1954.)[13]

Depot assignment of an aircraft or missiles mission usually preceded the actual activation of a specific associated workload at an installation by as much as several years while the weapons system was in the final states of R&D, and then test and evaluation. For the Matador, maintenance responsibilities for the weapons system at Robins became a reality in 1954, for both the missile and its portable launcher. On 9 March 1954, the 1st Pilotless Bomber Squadron deployed to Europe, for

the initial emplacement of the Matador (with a goal of operational status by mid-July). The Air Force planned the Matador for European deployment, and thus also needed an efficient method of shipping the missile overseas. The Matador could be disassembled into seven basic components, crated, and then loaded aboard transport aircraft for shipment (Plates 146-147)). Robins was the prime depot for the Matador, working with modifications through the B-61A, B-61B, and B-61C. Procurement totals for the Matador reached 582 "aircraft" in mid-1954.[14] At Robins, personnel retrofitted two World War II steel demountable, 130-foot span Butler hangars (originally Buildings 105 and 116) as packing and crating shops. Workmen enclosed both ends of the hangars (designed to be open-ended, with canvas drop cloths) and replaced gypsum siding with corrugated metal. Renumbering of the hangars as Buildings 602 and 603 also implies that the base moved the structures to a new location (from the flightline to a workshop area).[15] During the late 1940s and early 1950s, reuse of demountable Butler hangars occurred repeatedly at Air Materiel Command installations, suggesting that the moveable character of the hangars, as well as their probable storage as excess at Air Materiel Command depots, encouraged the Air Force to rely on these structures to fill immediate needs during the financially demanding period of the late 1940s and early 1950s. Examples of other bases turning to Butler hangars at this same time included Eglin (four, on the main flightline and at Field 3) and McClellan (two) (Plate 148).

During the early and middle 1950s, Air Materiel Command assigned the Warner Robins AMA responsibilities for the repair of several aircraft and associated components. In 1953, tasking included modification of 35 F-86Hs.[16] Other immediate assignments were:

- assembling, repacking, marking, and shipping aircraft parts;
- warehousing B-47 spares;
- responsibility for annual field maintenance and spares for 263 line items on Project Pine Tree;
- Inspection and Repair as Necessary (IRAN) duties for the B-29;
- overhaul of B-36 propellers;
- Project Right Way to develop data on the removal R-4360 aircraft engines;
- prime responsibility for the B-57A;
- prime responsibility for the AN/APA-54 and AN/APN-54A aircraft radar assemblies;[17]
- IRAN for the C (cargo) -122;
- Project Eagle Eye, for bombsight refurbishment; and,
- maintenance of the F-100C.[18]

Also during these first Cold War years, Air Materiel Command designated the Warner Robins AMA as the prime depot for the suspension and release equipment of atomic weapons and for the "portions of the loading handbooks for all types of aircraft designed to carry atomic weapons." Warner Robins personnel worked with their counterparts at the Oklahoma City (Tinker) and San Antonio (Kelly) AMAs on handbook sections pertinent to atomic weapons, with conferences on loading handbooks held at Kirtland Air Force Base in New Mexico during late 1953.[19]

As was the case with most Air Force bases in the continental United States, Robins underwent infrastructural improvements during the 1950-1955 years to support its growing missions. In 1955, construction began for a new runway to replace the three mile-long runways of World War II. Intended to accommodate the heavier bombers of the Cold War (especially the B-36 and the B-52), the middle 1950s runway at Robins was 10,600 feet long and 300 feet wide, cutting across two of the early 1940s runways and relegating the third existing runway to the status of a taxiway. Proximity of the Ocmulgee Swamp also necessitated additional land purchase, with considerable grading and fill.

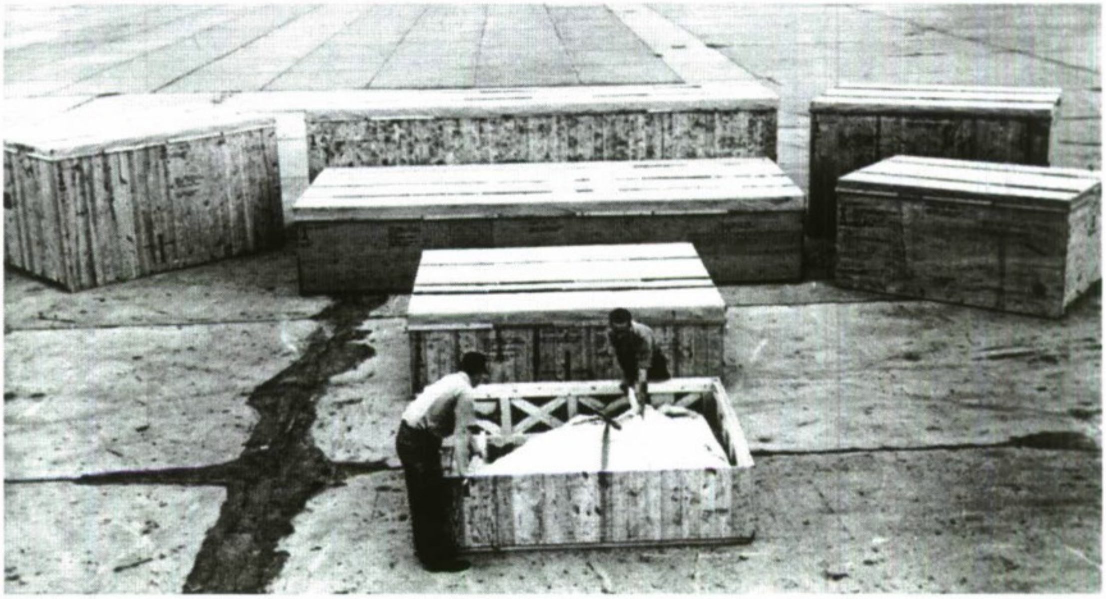

Plate 146: Martin Aircraft Company. Matador tactical missile, crates for shipment overseas, Robins Air Force Base. In *History of Warner Robins Air Materiel Area 1 January – 30 June 1954.*

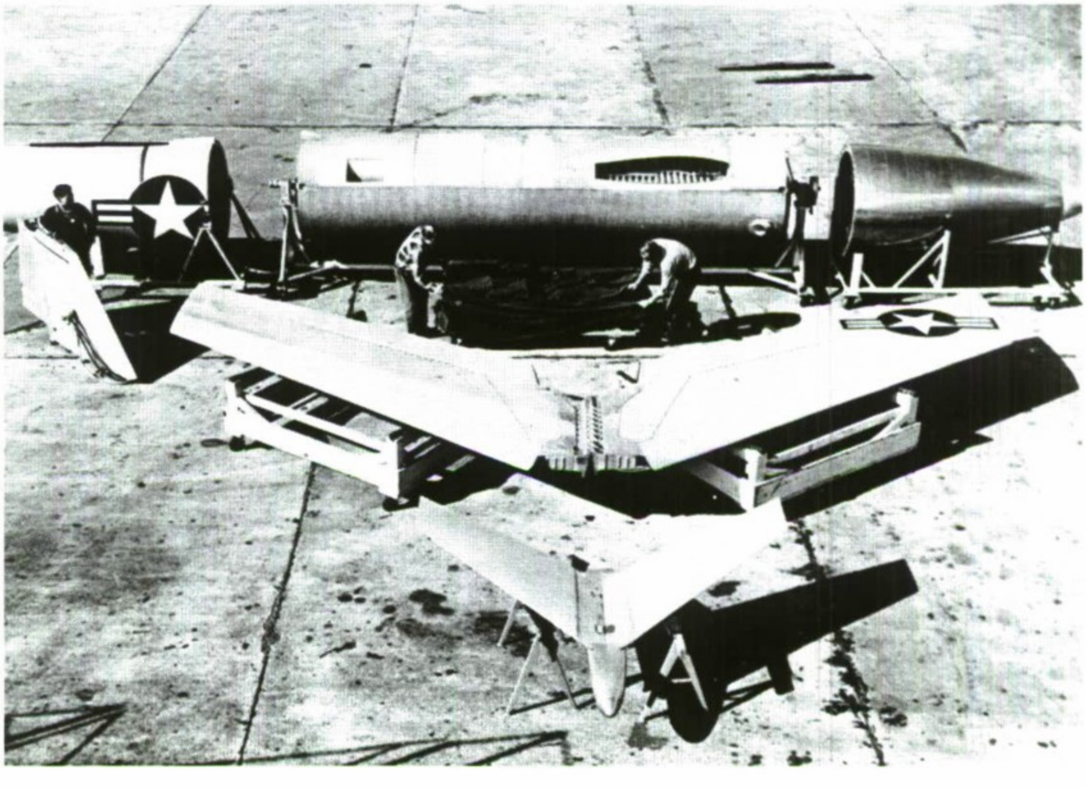

Plate 147: Martin Aircraft Company. Matador tactical missile, components laid out before crating, Robins Air Force Base. In *History of Warner Robins Air Materiel Area 1 January – 30 June 1954.*

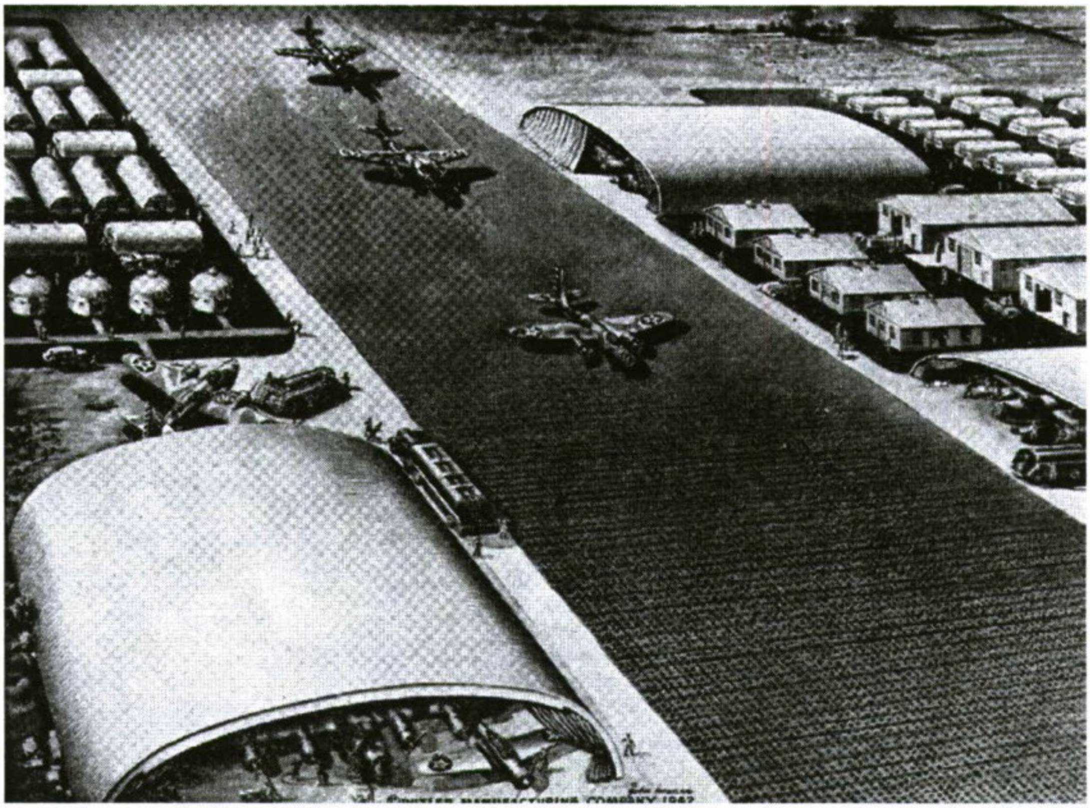

Plate 148: Butler Manufacturing Company. Composite of military products, including multiple kinds of buildings, Dymaxion deployment units, hangars, and landing mat. In *Engineering News-Record*, February 1943.

The runway was primarily of asphaltic concrete type. During this period, experimentation in runways varied from reinforced concrete pavement, to asphaltic concrete and pure asphalt surfacing, with a variety of base and sub-base treatments. Engineers designed the center 8,600 feet of the Robins runway as three material layers: a seven-inch thick "stabilized base of stone screenings mixed with natural earth;" an intermediate layer of "waterbound asphaltic concrete 6 inches thick;" and, an upper four inches of asphalt. The two ends of the new runway were each 1,000 feet long ("overruns") and featured solid reinforced concrete pavement 15 inches thick. These overruns complemented the 17-inch thickness of the center section (see Plate 143).[20]

The other major construction project at Robins during the first half of the 1950s was for two warehouses. (While Robins did add a standard readiness maintenance hangar in late 1952[21] [Building 149], this structure did not support an ADC fighter alert mission—as was the norm.) As a depot, Robins urgently required updated warehouses and was among the first of Air Materiel Command's bases to begin construction of the Special AMC Warehouse. Modern warehousing was a commandwide problem, and in early 1952 Air Materiel Command commissioned the architectural-engineering firm of L.P. Kooken of Baltimore to design a rigid-frame, reinforced concrete warehouse. The Special AMC Warehouse was modular and featured three variations in wall panels and two possible roof systems (see Volume I, Part II and Volume II, Chapters 6, 7, 10, 12, and 13). The most provocative of the L.P. Kooken warehouses relied on thin-shell precast wall and roof panels, a cutting edge construction technology at the outset of the 1950s. The Special AMC Warehouse appears to have had a regional prototype erected for the Oklahoma City AMA at Tinker in 1951 (the reverse of the more typical situation for Air Force building programs spread across multiple bases).

L.P. Kooken's first drawings for the Special AMC Warehouse date to April 1952. Air Materiel Command erected the warehouse in a range of sizes (modules) across both its AMA and specialized depots at 20 locations in the continental United States. In some instances, a base supported one Special AMC Warehouse, in others as many as three. The command erected the warehouse first at Griffiss Air Force Base in New York for the Rome AMA. The warehouse at Griffiss was a small structure built to store electronics equipment and was underway in October 1952. Air Force discussions suggest that the Special AMC Warehouses at Robins were among the first six under construction commandwide and may have actually predated the warehouse at Griffiss in design (see Volume I, Part II).

Air Materiel Command initiated construction of two Special AMC Warehouses at Robins in December 1952. Drawings for adaptation of the warehouse to the base are earlier than those for Griffiss and date to mid-September 1952.[22] The pair of Special AMC Warehouses at Robins (Buildings 380 and 385) were second in size only to a pair erected at McClellan Air Force Base (for the Sacramento AMA) during 1956-1957 (Plate 149). All Special AMC Warehouses were 400 feet wide. Lengths varied in modular increments from 400 feet (as at Griffiss) to 2,000 feet (as for one warehouse at McClellan). A railroad spur directly accessed these warehouses. The Robins pair included one warehouse 1,400 feet long, and the other 1,600 feet long. (Those at McClellan were 1,800 and 2,000 feet long, respectively.) The size of the East and West Coast Special AMC Warehouses at Robins and McClellan pointed to their use for large-quantity shipments overseas to Europe and Asia. Thin-shell reinforced concrete construction, as at Robins, was under intense discussion within the international engineering community during 1953-1954, in particular. The Navy Bureau of Yards and Docks was also in the midst of more than 7,000,000 square feet of thin-shell, reinforced concrete rigid-frame and precast panel warehouse construction at this same time

Plate 149: L.P. Kooken and Ammann & Whitney. Special AMC Warehouses (Buildings 380 and 385), Robins Air Force Base, 1952-1957. Photograph of February 2000. K.J. Weitze for EDAW, Inc.

(see Volume I, Part II). Completed at a cost of nearly five and one-half million dollars, Robins' Special AMC Warehouses were ready for beneficial occupancy in June 1955.[23]

The Special AMC Warehouses at Robins featured 15 identical storage units, each 200 by 400 feet. The buildings stood 24 feet high and had a total storage area of 27.57 acres. Automation and efficiency, not only in the construction system, but additionally in the warehousing system that the buildings fostered, was key.

> A towevyor system, about 1 ¼ miles in length, powered by 8 electric motors, operating within and between the structures, was capable of hauling 1500 loaded carts at the rate of 4 miles per hour. Railroad tracks were laid between the structures, each of which has truck loading ramps on one side and ordinary sprinkler systems throughout for fire protection. The Supply and Services Directorate which has prime responsibility for the distribution of over a million items to Air Force activities throughout the world, urgently needed the space in these buildings for the housing of materiel, some of which not authorized for outside storage, had to be kept unhoused and exposed to the weather.

Most noteworthy about the Special AMC Warehouses at Robins was what occurred during their construction between the close of 1952 and their occupancy in mid-1955. The professional engineering community entered into a very active and public debate on the rigid-frame system employed in the Special AMC Warehouse during 1955-1956, after the collapse of one span of the warehouse roof at Wilkins Air Force Station in Shelby, Ohio, in August 1955 (see Volume I, Plates 32-33) and a second failure in the Robins warehouse pair in 1956 (see Volume I, Part II). Yet, Headquarters Air Materiel Command was aware of problems at Robins from as early as late 1954. The rigid frames in one of the Special AMC Warehouses at Robins cracked in multiple places during original construction. Before completion of the structures (and not only as a retrofit after mid-1955), the Army Corps of Engineers and Air Materiel Command each inspected the failing Robins warehouse (then numbered as Building 702) and augmented the construction contract for additional steel. As studies of the situation at Robins continued, the commander of the Warner Robins AMA and the district engineer of the Savannah District of the Corps disagreed as to how to resolve the problems, or even how to determine what the problems were. A structural engineer with the Savannah District pinpointed several possible specific trouble spots, but the interim decision was to run load tests in accordance with the American Concrete Institute code and to allow occupancy of six of the seven damaged bays in the failing warehouse in January 1955. Robins planned to use its new warehouses with some added reinforcing, monitoring the structures monthly for the next year (into 1956). The situation remained at status quo until just after mid-August 1955, when Headquarters Air Materiel Command at Wright-Patterson notified all of its depots with Special AMC Warehouses that the roof of the Special AMC Warehouse at Wilkins had collapsed. Headquarters Air Materiel Command directed engineers at Robins to shore up the buildings immediately, to notify Headquarters of any additional cracking, and to produce marked drawings of the specific problems. A re-inspection at Robins was underway on 23 August—just six days after the collapse in Shelby, Ohio. Confirmed in the re-inspection were more cracks, some very serious. By the week of 29 August 1955, representatives from the Installations Division (civil engineering) of Headquarters Air Force in Washington, D.C., were enroute to Robins, and in early September surveys and drawings of both Special AMC Warehouses on base indicated that problems were major in each.[24]

Intent was to "establish responsibility for alleged design deficiency" in the Special AMC Warehouse program. The construction technology was one supported by some of the best engineers in the world

at the time, and the Special AMC Warehouse program of 1952-1955 was of high profile within not just Air Materiel Command, but also within the Air Force overall. What applied to the Special AMC Warehouse might apply to other Air Force (and presumably, Navy) construction of parallel type. For example, during 1953-1954, the Atlantic District of the Army Corps of Engineers hired Roberts & Schaefer of Chicago to execute a similar rigid-frame, thin-shell panel design for multiple buildings (including dormitories) at Lajes Air Base in the Azores. Roberts & Schaefer was one of the key international firms executing thin-shell construction, particularly long- and short-barrel arched structures for hangars and warehouses for the Army, Air Force, and Navy (see Volume I, Part II). The pair of Special AMC Warehouses at Robins became the case study for Air Materiel Command and the Air Force. On 20 September, a highly qualified team examined the warehouses. Team members included Dr. Siess of the University of Illinois (whose civil engineering department worked closely with Air Materiel Command over an extended period during the Cold War—see Volume I, Part III); Dr. Hanson of the Massachusetts Institute of Technology (MIT) (MIT worked very closely with ARDC during this period and later); Mr. Westrich, Headquarters Air Force; Mr. Germundson, of the Portland Cement Company; Mr. Cohen of the New York engineering firm Ammann & Whitney; Mr. Zackrison of the Robins civil engineering office; and, Mr. Willis of the Savannah District of the Army Corps of Engineers. Detailed load testing and studies of structural deficiencies using radioactive Cobalt 60 to locate the reinforcing steel and stirrups in the concrete framing, as well as deficiencies in the steel within the concrete, continued steadily through December 1955.[25]

Air Materiel Command, through the Army Corps of Engineers, hired Ammann & Whitney, a prominent firm and among the leaders in thin-shell reinforced concrete construction during the 1948-1955 period, to prepare a report analyzing the Special AMC Warehouse and to recommend corrections. Ammann & Whitney studied the warehouse pair at Robins, as well as data from warehouses at other Air Materiel Command installations, and concluded that the failures had not occurred due to faulty construction materials or methods. Ammann & Whitney laid the blame on selected design deficiencies in a construction technology that was futuristic and not completely understood. Key issues were frozen (rigid) joints and roof slabs that were not integral to the girders beneath them. Ammann & Whitney prepared sheets of drawings revising the original design of L.P. Kooken in early 1956. In all cases, the cracking in the AMC Special Warehouses had occurred either during construction or within the first two years. Most of the AMC Special Warehouses were already in place by the date of the Ammann & Whitney changes, requiring them to be retrofitted with additional steel stirrups—as was true at Robins in January 1957.[26] At the McClellan depot, the greater part of the learning process predated the beginning of construction for the Special AMC Warehouse pair there. In that case, the warehouses included the Ammann & Whitney improvements before workmen initiated construction on site (see Volume II, Chapter 10). The Special AMC Warehouses are still in use at all active bases possessing them and continue to be valuable infrastructure 50 years after their original design.

While the controversy over the pair of Special AMC Warehouses was in progress at Robins during late 1954 through 1955, the depot desperately needed more storage and supply space. In 1955, Air Materiel Command decided to erect additional standard warehouses at the installation as a safeguard measure. The secondary three warehouses, Buildings 350, 368, and 660, were not clustered together in the same manner as the Special AMC Warehouse pair, but did offer 800,000 square feet of storage nearly immediately. These warehouses were two-thirds completed by the end of 1955, with full operations in August 1956—before the same status could be sustained for the Special AMC Warehouses (which were under construction on base in late 1952). Also of concrete construction, the three structures featured truck loading ramps and connections to other installation facilities via a little over a mile of railroad track.[27] Implied in discussions of the three warehouses of 1955 was a temporary return to more traditional construction technology, although their size and configuration

reflected modular dimensions that were very similar to those of the Special AMC Warehouse. Two of the warehouses were 600 by 400 feet; one, 800 by 400 feet.[28]

Planning and construction for both the 10,600-foot runway and the pair of Special AMC Warehouses consumed much attention at Robins during the early and middle 1950s as the base added administrative buildings and anticipated Air Materiel Command missions of later in the decade. The installation also aborted receipt of a high-profile large-aircraft repair hangar. In September 1952, Headquarters Air Materiel Command at Wright-Patterson planned to construct two identical hangars at Kelly and Robins, for the San Antonio and Warner Robins AMAs, respectively. The command discussed its intentions with the Air Installations Division of Headquarters Air Force in Washington, D.C. The hangar was an extremely unusual one, designed and engineered by the Kuljian Corporation in Philadelphia. Kuljian had completed its design of a double-cantilever hangar to accommodate the B-36 only a year earlier. The firm had developed three variations for double-cantilever hangar in a basic, medium, and large size (for maintenance on two to six B-36s). The Air Force erected approximately 55 double-cantilever hangars throughout the continental United States and at several bases overseas, in a steady construction program of 1952-1957. The large-aircraft repair hangar was a follow-on to that benchmark achievement (see Volume I, Part IV). The Kuljian large-aircraft repair hangar of autumn 1952 was 2,000 feet long, 300 feet wide, and 91 feet high, with attached shops. Consisting of five modular units, each 400 feet long, the hangar was actually five hangars in a row and relied on two double-hinged, rigid-frame double-cantilever steel trusses. The hangar's function was to handle the overhaul of large bombers, such as the B-36 and B-52, in an assembly line. Men could work on as many as 10 B-36s, or 14 B-52s, inside the hangar at one time, moving the aircraft from one end to the other, exiting the hangar opposite the entry. Air Materiel Command built the oversized hangar only once, however, at Kelly. (The San Antonio AMA planned to use the hangar for B-36 repair, but instead adopted the hangar for IRAN on the B-47 in late 1956—and later, for overhaul of the B-52 and C-5). Air Materiel Command and Headquarters Air Force had discussed a second large-aircraft repair hangar at Robins at a projected cost of $11,305,000.[29] Instead, in 1956 the Air Force decided to substitute nose docks for a permanent repair hangar at Robins. Air Materiel Command issued a contract of over $765,000 for preparation of a concrete hardstand as "an outside work space for aircraft." Men moved in nose docks at each plane "as shelter while work is being accomplished on engines"—a process more typically given up by the middle 1950s at most Air Force bases.[30]

During the second half of the 1950s, Air Materiel Command continued to assign repair, maintenance, and overhaul missions to the Warner Robins AMA. In 1956, the major new assignments were related to armament. As armament systems for aircraft became more complexly electronic, planes included an increasing number of fully self-contained units "designed to do a special job, having a specialized circuit, and being beyond overhaul capability except at a specialized depot." The command referred to these units as black boxes. For example, the E-1 fire control system had 36 individual black boxes. Whereas the San Antonio AMA at Kelly might be assigned the airframe modifications for the F-86D, the Warner Robins AMA received the task of modernizing the fighter's fire control system (Project Pull Out). Another of many specific projects of the period was preparing the F-86K, a version of the F-86 developed for European countries. Through Project Pot Shot, Robins personnel provided "support spares in each country and a complete range of tools and test equipment for overhaul."[31] Other aircraft modification for overseas included efforts on the F-100 for European installations and on the B-57 for bases in Japan, both in 1956, as well as overhaul of the refueling tanker, the KC-97.[32] The B-57 was an especially significant assignment at Robins during the middle 1950s and following. Similar to the depot's work on the Matador, F-86K and F-100, Robin's efforts on the B-57 were geared toward supply overseas, including both Europe and Asia. In spring 1956, Tactical Air Command (TAC) had 66 B-57s deployed to two installations in the continental United States and the remaining 119 to Germany, France, and Japan. In addition, the Air Force placed small numbers of

the fighter-bomber at ARDC and other installations for testing and special missions (at Biggs, Kelly, and Sheppard in Texas; Edwards in California; Eglin in Florida; Kirtland in New Mexico; Shaw in South Carolina; and, Wright-Patterson, as well as at five military contractor locations). At this time, 32 B-57s were also at Robins for overhaul, with others at the depot for special modifications.[33] The B-57 remained active in Air Force inventory until August 1979.[34] The Warner Robins AMA generally processed TAC production aircraft for overseas delivery.[35]

In mid-1957, Headquarters Air Materiel Command began grouping maintenance and overhaul assignments by families of aircraft and missiles. The change shifted command policy from one focused on clustering depot responsibilities by aircraft and weapons systems manufactured by single companies (all Martin systems at a single depot), to a policy placing bombers, fighters, and cargo aircraft at distinct depots. The command carried this concept forward to a segregation of tactical, strategic-ballistic, strategic-cruise, guided air rocket, and interceptor missiles. Under the new plan, Robins became the prime depot for the C-130, a large cargo transport aircraft. Previously, the probable location for the C-130 mission was the Sacramento AMA at McClellan (the depot that supported Lockheed systems). (Although manufacture of the C-130 was in Georgia, at Lockheed's plant in Marietta—Air Force Plant [AFP] 6.) Under the old organizational hierarchy, Robins could also have anticipated receipt of Martin's Titan intercontinental ballistic missile (ICBM) as a follow-on to its mission for the Matador. Instead, the Titan went to the San Bernardino AMA at Norton in Southern California. Although Air Materiel Command policies would change yet again during the 1960s, due to the availability of specialized facilities (such as the oversized maintenance hangar at Kelly, adaptable for the C-5) and to depot closures (for the Middletown AMA at Olmsted Air Force Base in Pennsylvania and the San Bernardino AMA at Norton). In the late 1950s, however, the Warner Robins and San Bernardino AMAs received all cargo transport aircraft. The command also assigned the Warner Robins AMA the tactical missile (TM) group. The Mace, TM-76, replaced the Matador (and the Air Force redesignated the Matador from the B-61 to the TM-61).[36] During the late 1950s, Robins geared up for IRAN responsibilities for the C-130 and prime tasking for the Mace, still in development. Other depot assignments included overhauls for multiple types of aircraft propellers and prime responsibility for the C-54—a cargo plane in heavy service during the immediate post-World War II years.[37]

Closely following the assignment of overhaul and modification for transport aircraft, Robins received its first major tenant mission. The base became one of 65 Air Force installations supporting SAC alert. Both future cargo planes and SAC's B-52s (and KC-135s) required infrastructural improvements at the base, particularly another extension of the runway to 12,600 feet. Plans were for a 1,000-foot addition at both ends (Plate 150). Base engineers also prepared to construct reinforced concrete aprons for heavy aircraft, planning for aprons that were 15 to 20 inches thick.[38] SAC announced its intentions for Robins during spring 1958. The 4137th Strategic Wing arrived at the installation in February 1959. The SAC alert compound at Robins included not just the standard readiness crew quarters (molehole) and its associated herringbone alert apron (Christmas tree), but also Hound Dog and Quail run-up shops, a combined service shop, and weapons-specific storage (see Volume I, Part IV and Volume I, Plate 102). The Hound Dog was the first nuclear-tipped cruise missile, carried as a pair on the underside of the B-52 (see Volume I, Plate 100). Its decoy, the Quail, deceived enemy radar as an inbound bomber. SAC's highest priority alert locations received both the Hound Dog and the Quail, including the 4137th Strategic Wing at Robins. Of its units on alert, SAC armed 29 with the Hound Dog, providing 14 of these also with the Quail. At installations where SAC was a tenant, such as Robins, the command also built a larger compound of support structures away from the immediate alert area. In its most mature configuration, the compound included three composite structures, an operations building (command post), an industrial building, and a warehouse. The full complement of SAC alert infrastructure was represented at Robins: a 70-man

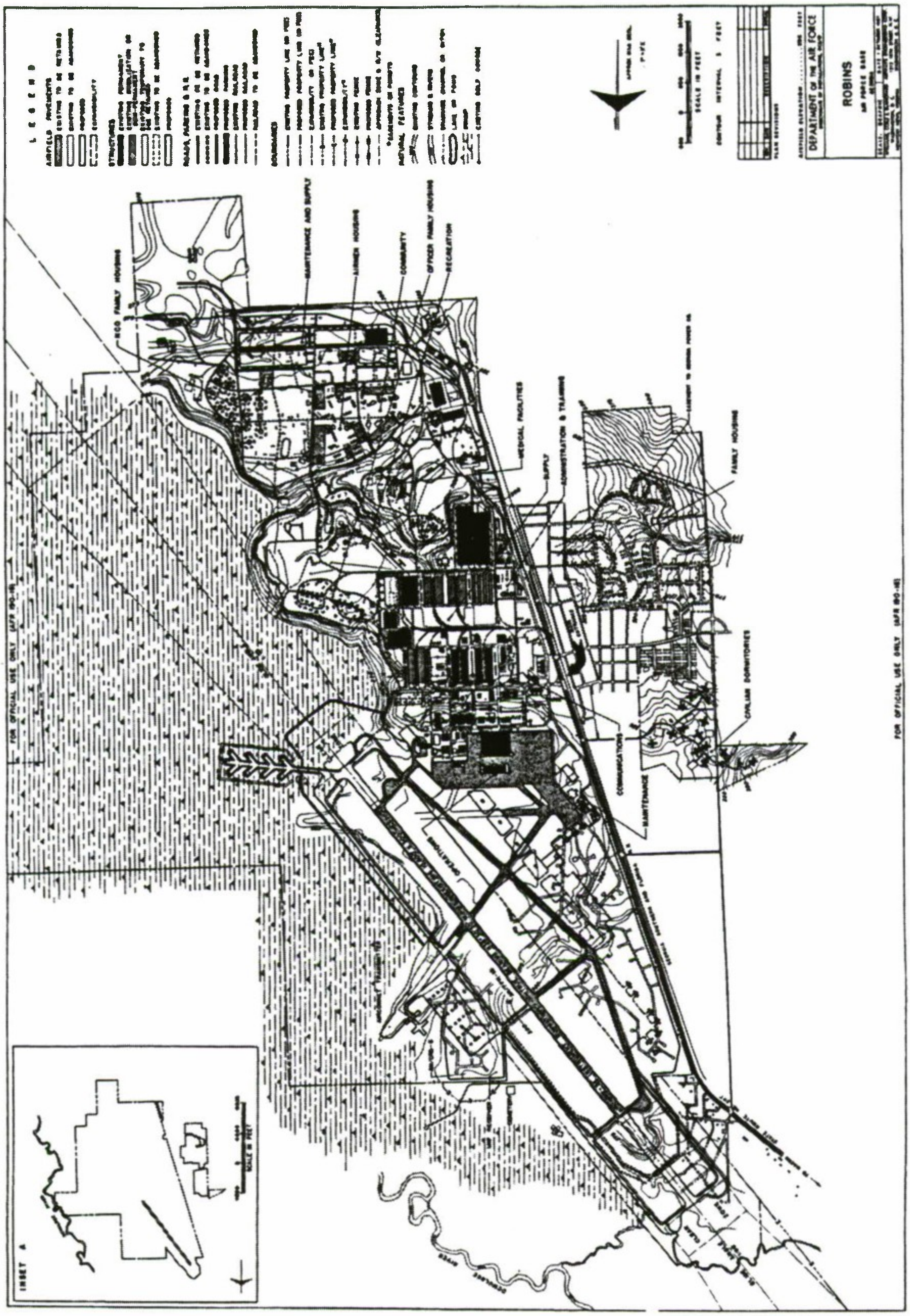

Plate 150: Directorate of Installations, Headquarters United States Air Force. Master Plan for Robins Air Force Base, October 1957. Collection of K.J. Weitze.

molehole by Leo A. Daly of Omaha (Building 12), an eight-to-nine stub alert apron, the composite buildings by Giffels & Rossetti of Detroit (Buildings 78 and 79), the Hound Dog and Quail run-up and service shops by Ganteaume & McMullen of Boston (Buildings 75, 76, and 86), the B-52 and KC-135 nose docks bracketing a rectangular refueling apron (Buildings 52, 66, 67, 81, and 82), and nuclear munitions storage igloos by Black & Veatch of Kansas City (Buildings 94, 97 and 98) (see Volume I, Part IV). (The compound existed in its entirety in 2000.) Somewhat unusual at Robins was the addition of a guided missile maintenance shop for the Hound Dog and Quail, incorporated within the main base (Building 614) and a joint SAC – Air Materiel Command washrack and personnel decontamination center (see Volume I, Plate 103). The SAC alert mission at Robins was one of three in Georgia. (The others were at Hunter and Turner Air Force Bases). The 4137th Strategic Wing went to high alert conditions during the Cuban missile crisis of October 1962, with eight B-52s on ground alert, followed by a one-eighth airborne alert. The 4137th Strategic Wing stayed on alert at Robins until early 1963. Thereafter, SAC stationed bombardment squadrons at the installation through the close of the Cold War.

Depot missions at Robins at the end of the 1950s included more assignments focused on armament support (for the F-102 and the B-52) and executive management responsibility for the C-130. The first C-130A was on the modification line in August 1958. ARDC evaluated the C-130 as an assault transport aircraft, able "to land and off-load troops and supplies on unprepared terrain and to fly out the wounded" Testing of the C-130, important to the overhaul and modification mission for the aircraft at Robins, took place on the ranges at Eglin in the Florida panhandle. At Eglin, ARDC assessed "take-offs, landings, and taxi-runs in bush-covered, sandy loam, rough, unprepared fields" (Plate 151). ARDC also evaluated the C-130's ability to land and take off on snow-covered ice, testing a C-130 weighing 92,976 pounds on the frozen surface of Lake Bemidji in Minnesota (Plate 152). TAC planned to use the C-130 in Arctic and Antarctic areas. To accommodate that mission, Robins personnel installed a ski-and-wheel addition to 12 of the transports. Landing skis were 19.5 feet long. Yet another modification of the C-130 was one for aerial photography capabilities, and at the end of the 1950s an important project went forward for short take-off and landing (STOL). To achieve STOL for the C-130, Robins engineers augmented a test bed aircraft with two additional jet engines. The increased number of engines controlled the air around the plane during landing and take-off, referenced as a Boundary Layer Control (BLC) system. TAC intended C-130s modified with a BLC system "for take-offs and landings when the field lengths are extremely short, such as would be the case in a forward combat zone."[39]

During the 1960s, Robins—like a number of Air Materiel Command and ARDC installations—hosted two prototype structures for the Air Force at large. The phenomenon is not thoroughly researched, but does appear to be more common at bases within these two commands than at bases subsumed beneath other Air Force commands (see Volume II, Chapters 3 and 10). Most often, the structures incorporated prefabricated components, or repetitive steel or reinforced concrete modules. The occurrence of prototypes may be related to the civil engineering role filled by Air Materiel Command for the Air Force, sometimes strengthened through the R&D mission of ARDC (see Volume I, Part III). At Robins, AFLC (the follow-on to Air Materiel Command) erected the pilot SAC fuel systems nose dock (Building 52) during 1961. Within the following several years, fuel systems nose docks, usually one per installation, went in place at SAC bases, and always where SAC sustained a tenant alert mission. SAC planned 10 fuel systems docks for construction during Fiscal Year (FY) 1961, docks procured and erected by Air Materiel Command / AFLC. The fuel systems dock at Robins was the first erected at Air Force Bases nationwide, to be followed by fuel systems docks at Blytheville in Arkansas; Clinton-Sherman in Oklahoma; Glasgow in Montana, Grand Forks and Minot in North Dakota; Kincheloe, K.I. Sawyer, and Wurtsmith in Michigan; and, Wright-Patterson.[40]

Plate 151: ARDC tests of the C-130 modified as an assault aircraft, on the ranges at Eglin Air Force Base. The aircraft sank 1.5 to 2 feet into the sandy loam during both landings and take-offs. In *History of Warner Robins Air Materiel Area 1 July – 31 December 1958.*

Plate 152: ARDC ski-and-wheel version of the C-130 in test on the frozen surface of Lake Bemidji, Minnesota. Showing the modified C-130 taking off loaded at a world-record weight of 92,976 pounds. In *History of Warner Robins Air Materiel Area 1 July – 31 December 1958.*

In November 1963, AFLC issued criteria for a large-aircraft paint hangar at Robins, the first Air Force facility of its type intended to accommodate the largest planes in Air Force inventory.[41] The command had approached the paint-hangar problem set once before during the early Cold War period and had also sponsored the development of an interim corrosion control facility. In the middle 1950s, Air Materiel Command had commissioned a state-of-the-art paint hangar of precast, prestressed reinforced concrete construction at Hill (for the Ogden AMA). That hangar featured a 130-foot clearspan, and was the work of Roberts & Schaefer of Chicago. (Roberts & Schaefer was best known for their thin-shell designs.) The Hill hangar was not appropriate for very large aircraft (see Volume II, Chapter 6). In 1960, AFLC contracted for a corrosion control facility, a nose dock able to handle one large aircraft as a standard corrosion control shelter. Giffels & Rossetti designed the Corrosion Control Facility for buildout at Air Force installations in November 1960. (The year before, the Detroit firm had handled the design of the Hound Dog and Quail run-up and service shops.) The corrosion control nose dock incorporated hinged, trussed arches, suggestive of a prefabricated (or demountable) hangar. Clearspan was over 250 feet, with doorways offering wing clearance to about 201 feet and tail height clearance to about 59 feet. The depth of the corrosion control nose dock was 144 feet, with an additional 36-foot projection to accommodate the nose of a large aircraft.[42] The Air Force had released a "criteria design brochure" of the preliminary Giffels & Rossetti corrosion control shelter to the metal building industry after a field trip to Detroit in May 1960, with the purpose of "soliciting and procuring pre-engineered metal structures" during FY 1961.[43] In late 1961, the Air Force instituted a formal policy of "utilizing pre-engineered metal structures where-ever appropriate"—especially emphasizing the employment of prefabricated buildings for "selected aircraft maintenance structures and aircraft shelters."[44] Air Materiel Command did not erect a new paint hangar at Robins during 1964, choosing instead to erect Giffels & Rossetti's nose dock of 1960. Engineering personnel adapted the nose dock to include "an air handling system that filters and conditions the air to a standard necessary for the application of acrylic paints and lacquers with [the] latest paint equipment."[45] The facility presumably accommodated cleaning and painting for the C-130 transport, as well as that for other cargo aircraft assigned to the Warner Robins AMA. In 1968, AFLC did build the full-scale paint hangar planned several years earlier—at McClellan Air Force Base in Sacramento (see Volume II, Chapter 10). The McClellan hangar remained nearly identical in size to the original Giffels & Rossetti nose dock of 1960. In late 1974, AFLC again chose to rely on its existing facility at Robins (Building 89), expanding the dock through a front modular addition of 36 feet (continuing the hinged trussed archwork), a rear addition of lesser size, and inside removal of shop walls to allow larger transport aircraft [46] (Plate 153). Only in the early 1980s did the Robins initiate construction for a state-of-the-art painting and cleaning hangar, completed in early 1985.[47]

Missions at Warner Robins during the 1960s continued to focus on overhaul and modification of transport aircraft. Assignments also included the Mace tactical missile as planned. In early 1961, Air Materiel Command designated the Warner Robins AMA as the logistics support manager for the jet cargo plane in development, the C-141A. Like the C-130, the C-141 was a Lockheed aircraft manufactured at AFP 6 in Marietta, Georgia (see Volume II, Chapter 15). Two more Air Force tenants arrived at Robins, the Air Rescue Service and Continental Air Command (CONAC). CONAC's presence was a major one, with headquarters for the command transferring its operations from Mitchel Air Force Base on Long Island, New York, to Robins. Transport depot missions began to shift from the San Bernardino AMA in Southern California to the Warner Robins AMA, including those for the C-124 and C-133. As the decade progressed, the Warner Robins AMA managed the C-47, C-54 (with maintenance executed through contractors), C-53, C-118, C-119 (including it gunship version, the AC [attack cargo] -119), C-123, and AC-130 (the gunship version of the C-130), also handling an analytical repair program for the SH (search-and-rescue helicopter) -3E. The depot continued its efforts for the B-57.[48] For the TM-76A Mace, Robins personnel modified 96 of the

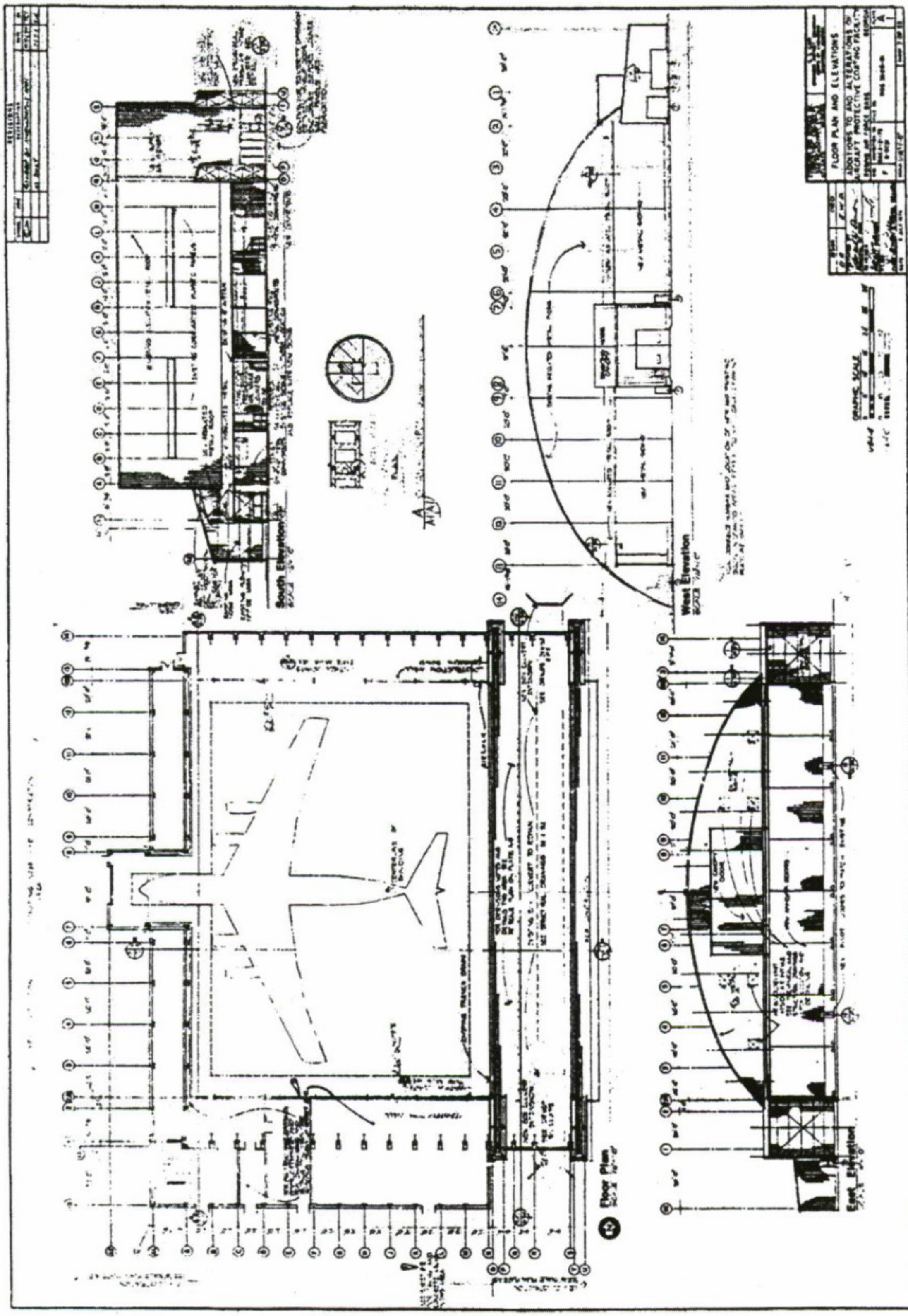

Plate 153: Giffels & Rossetti. Corrosion Control Facility, Robins Air Force Base, November 1960 (adapted at the installation during 1963-1964). Courtesy of Civil Engineering, Robins Air Force Base.

missiles and 111 nose cone (warhead) sections for the Rapid Fire Multiple Launch (RFML) program. Reconfiguration to RFML required contractor and military field teams at overseas sites. The teams completed the first conversions in March 1961. Simultaneously, category II testing went forward for the TM-76B Mace at Patrick Air Force Base in Florida. The Warner Robins AMA managed depot maintenance contracts directly with Martin, the manufacturer of the Matador and Mace. Martin operated a depot maintenance facility at its plant in Baltimore for the Matador, as well as two similar facilities overseas at Bitburg, Germany, and Tachikawa, Japan. For the Mace, the Warner Robins AMA contracted with Goodyear for depot-level maintenance at its plant in Akron, Ohio, and at a facility in Sembach, Germany. Robins also contracted for related equipment overhaul efforts in Orlando, Florida. Martin sustained maintenance contracts with the Warner Robins AMA for the Mace, including ones for a maintenance depot in Sembach, one in the Pacific theater, and one in Baltimore.[49]

The Mace program of the late 1950s into the middle 1960s was one focused on a weapons system for American air bases overseas, as had been true of the tactical missile's predecessor the Matador. Throughout the period generally, the overhaul, modification, and maintenance workload of the Warner Robins AMA concentrated on both aircraft and weapons systems designated for abroad—including the B-57, F-86K, F-100, Matador, and Mace. Deployment of these weapons systems emphasized a breakdown into shippable components, with appropriate preparation and processing at Robins. The Mace, like the Matador, was a pilotless aircraft, 44 feet long with a wingspan of 23 feet. Launchers for the Mace were both fixed and mobile (such as the RFML configuration). The Air Force fixed launcher for the Mace featured a type of protective, and then hardened, construction. At selected overseas bases, the Air Force fired the Mace from a zero-length launcher (ZEL). The Air Force erected the ZEL at American bases in Germany and Japan at the outset of the 1960s. The ZEL sat in a two-bay shelter that housed one fighter aircraft (the F-100) and one Mace missile.[50] The Directorate of Installations at Headquarters Air Force had noted that the Air Force had first planned Mace launch complexes as "unhardened," but had revised launch complexes as "hardened" to 200 pounds per square inch (psi) in mid-1958. ARDC erected the prototype two-bay shelter for the ZEL at the Missile Development Center at Holloman in 1958-1959, for what the Air Force Directorate of Operational Requirements described as the Missile Shelter Program. To achieve a positive angle of attack, personnel elevated the launching platforms (similar to flatbed trailers) for all Mace firings. ARDC tested the Mace heavily at Holloman into 1960-1961, thereafter at its Missile Test Center at Patrick. The ZEL shelter tested at Holloman was an economical protective launch configuration, complemented by a concrete-arch prototype launcher built at Patrick (Plate 154). The Air Force emplaced the Mace at Sembach and Hahn, Germany, during FY 1959 and at Bitburg, Germany, and Kadena, Japan, during FY 1960 and FY 1961. Construction delays for the Mace A and B (TM-76A and TM-76B) pushed completion of the launch sites into 1963, with additions to Sembach and Hahn.[51]

The Warner Robins AMA also supported American efforts during the Vietnam War. In early 1965, TAC began to deploy the B-57 to Southeast Asia. Later that year, the Air Force included Robins personnel in Project Red Horse. Civil engineering squadrons from Robins rotated to Vietnam and Thailand to build bases. Red Horse concentrated on construction of prefabricated structures, including cantonment buildings and aircraft revetments and shelters (see Volume II, Chapter 3). Training for TAC Red Horse squadrons was occurring simultaneously on the ranges at Eglin, as was experimentation through ARDC for revetments, prototypes for aircraft shelters, prefabricated dormitories, inflatable hangars, and rapid runway repair. Many, if not all, of the AFLC depots had assigned responsibilities for specific prefabricated items (revetments, shelter liners, inflatables, runway landing mat) (see Volume II, Chapters 10 and 13). Many also supported TAC's Bare Base concept (with testing at Eglin), the case for the Warner Robins AMA. Specific assignments at Robins

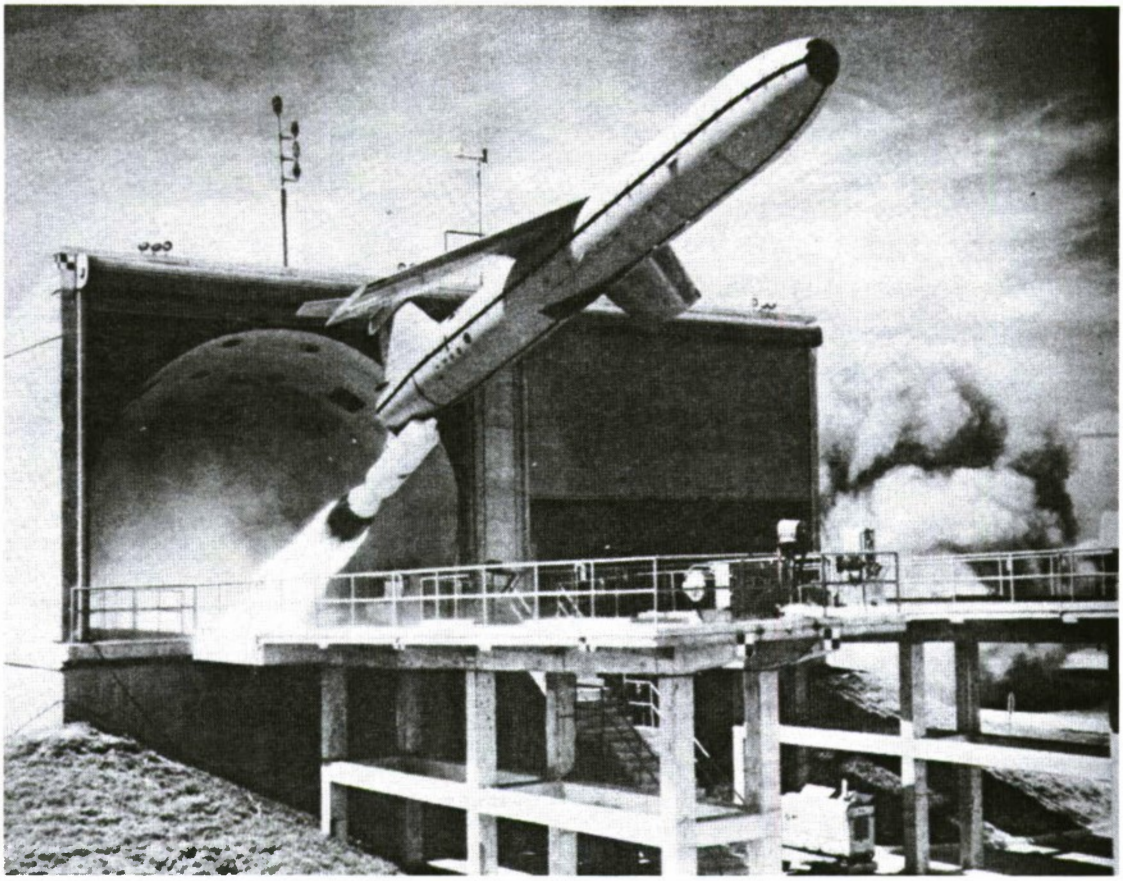

Plate 154: Mace Launch, Two-Cell R&D Shelter, Complex 21, Patrick Air Force Base, Florida, 1959-1960. In *Air Force Civil Engineer*, May 1961.

included storage and shipment of AM-2 runway matting (employed directly for Bare Base), bomb-damage repair (BDR) patch kits (also developed and tested at Eglin), and Porta-Kamps of various sizes used by multiple commands beyond their activities in Southeast Asia.[52] Also true for the depots, the Warner Robins AMA supplied spare parts to the theater bases and handled individual taskings such as the overhaul of optical sights for the F-4. Increments of AC-119 gunships modified at Robins deployed in rounds to Vietnam throughout the late 1960s. Warner Robins AMA personnel additionally contributed to English-Vietnamese maintenance manuals, distributed to airmen of the Republic of Vietnam for aircraft and vehicular repair work.[53]

Missions assigned to the Warner Robins AMA / ALC during the 1970s included one that moved the depot away from the support of transport aircraft and tactical missiles. With consolidation of depots after the middle 1960s, and with concentration on the Minuteman ICBM and selected interceptor and cruise missiles, the missile depot assignments fell almost entirely to the Ogden AMA at Hill. In part to assure viability of the logistics mission at Robins, as of 1969 AFLC placed a new type of tasking at the installation—that for the advanced F-15 (then in initial development). The McDonnell Douglas F-15 made its first flight in late July 1972. Air Force Systems Command (AFSC) (the follow-on to ARDC) tested the fighter at the Air Force Flight Test Center at Edwards into the middle 1970s. The first F-15 arrived at Robins in November 1974 and a maintenance repair mission for the aircraft began in May 1975 (indoctrination). The F-15 missions accrued steadily at Robins after May 1977. At times, similar to past situations, the Warner Robins ALC deployed maintenance teams to operational sites, rather than receiving the aircraft at the depot. One such instance occurred in early

1981, when the Warner Robins ALC sent a field team to Eglin to modify 83 F-15s assigned to TAC. In the early 1980s, Robins added a final checkout and assembly facility, as well as an x-ray facility, for the overhaul and maintenance of the F-15. The F-15 mission at Robins continued to be a major one beyond the end of the Cold War. Other aircraft overhaul and modification projects coming to the Warner Robins ALC included Air Force helicopters (as well as sustained support for cargo aircraft). AFLC also continued missiles work at Robins after the Mace, assigning the Advanced Medium Range Air-to-Air Missile (AMRAAM) to the depot in January 1980.[54] In 1981, AFLC assigned missions associated with the future B-1 to the depot, although did not place prime responsibility for the bomber at the Warner Robins AMA. (The first B-1 came off the assembly line at Lockheed at AFP 42 in Palmdale, California, in late 1984.) In autumn 1995, well after the end of the Cold War, the Georgia Air National Guard (ANG) received the B-1 for the 116th Bomber Wing at Robins (in the late 1950s SAC alert area). Robins is one of six installations with the bomber today.[55]

A late Cold War example of shippable, prefabricated infrastructure handled at the Warner Robins ALC was that of the Hayman igloo in the late 1980s and early 1990s. Named after Lowell Hayman (who conceived the idea of the structure), the igloo was nearly a mortise-and-tenon construction—a concrete and steel, rectangular box 96 by 22 feet, of economical cost.[56] Walls, roof sections, and roof caps were precast concrete, and styrofoam fills the steel cavity doors. AFLC intended to use the igloo in war theaters, although the command first used the structure in Europe (where the Air Force removed nuclear weapons and replaced them with traditional munitions). A standard igloo required between three and four months to erect, while three men could set up a Hayman igloo in a week. Men then buried the Hayman igloo in two feet of dirt, typical of a standard igloo—but personnel could still dismantle the structure and move its components to another location should that be desired. Between 1985 and 1990, munitions specialists from the Air Force Weapons Laboratory (AFWL) at Kirtland, working with team members from the New Mexico Engineering Research Institute (NMERI) in Albuquerque, ran two phases of tests on the Hayman igloo on the Utah Test and Training Range (UTTR) associated with Hill. The most spectacular UTTR test was Great Balls of Fire in 1988, when AFWL and NMERI personnel erected a cluster of Hayman structures and detonated 500,000 pounds of explosive charge inside the center igloo to test quantity-distance relationships[57] (see Volume II, Chapter 6). Undated NMERI drawings exist for the Hayman igloo (the H-2 Building) (Plate 155) as executed through the Savannah District, Army Corps of Engineers, for the Warner Robins ALC.

Toward the end of the Cold War, at the height of the conflict's resurgence during the Reagan presidency, Robins also hosted a second major tenant mission: a PAVE PAWS radar. PAVE PAWS derived from work toward large phased-array radar beginning in the late 1950s. The first such radar had been the Bendix AN/FPS-85 at Eglin.[58] The AN/FPS-85 was under construction in the early 1960s, but due to a catastrophic fire had required rebuilding at mid-decade. The Air Force, through Aerospace Defense Command (ADC), took charge of the AN/FPS-85 in late 1968 (followed by SAC and then AFSPC). Progressive improvements in large phased-array radar continued through the period that the AN/FPS-85 was in development, test, and construction—focused primarily on radars for an antiballistic missile defense system (with one radar of the tracking type built in North Dakota) and on intelligence-surveillance (with Cobra Dane erected on Shemya in the Aleutians off the Russian coast). Those radars became operational in the middle 1970s. By the early 1970s, the threat of improved Soviet SLBMs also led to planning for PAVE PAWS. Originally planning for multiple installations ringing the continental United States, the Air Force intended PAVE PAWS as a powerful SLBM and ICBM warning radar capable of tracking missile launches. The Electronic Systems Division (ESD) at Hanscom Air Force Base near Boston managed the PAVE PAWS program, working with the radar and electronics laboratories at Griffiss in New York (the Rome research laboratories). Raytheon, the contractor for the system, built the first two PAVE PAWS at Cape Cod, Massachusetts, and at Beale Air Force Base, north of Sacramento, California, between 1977-1980.

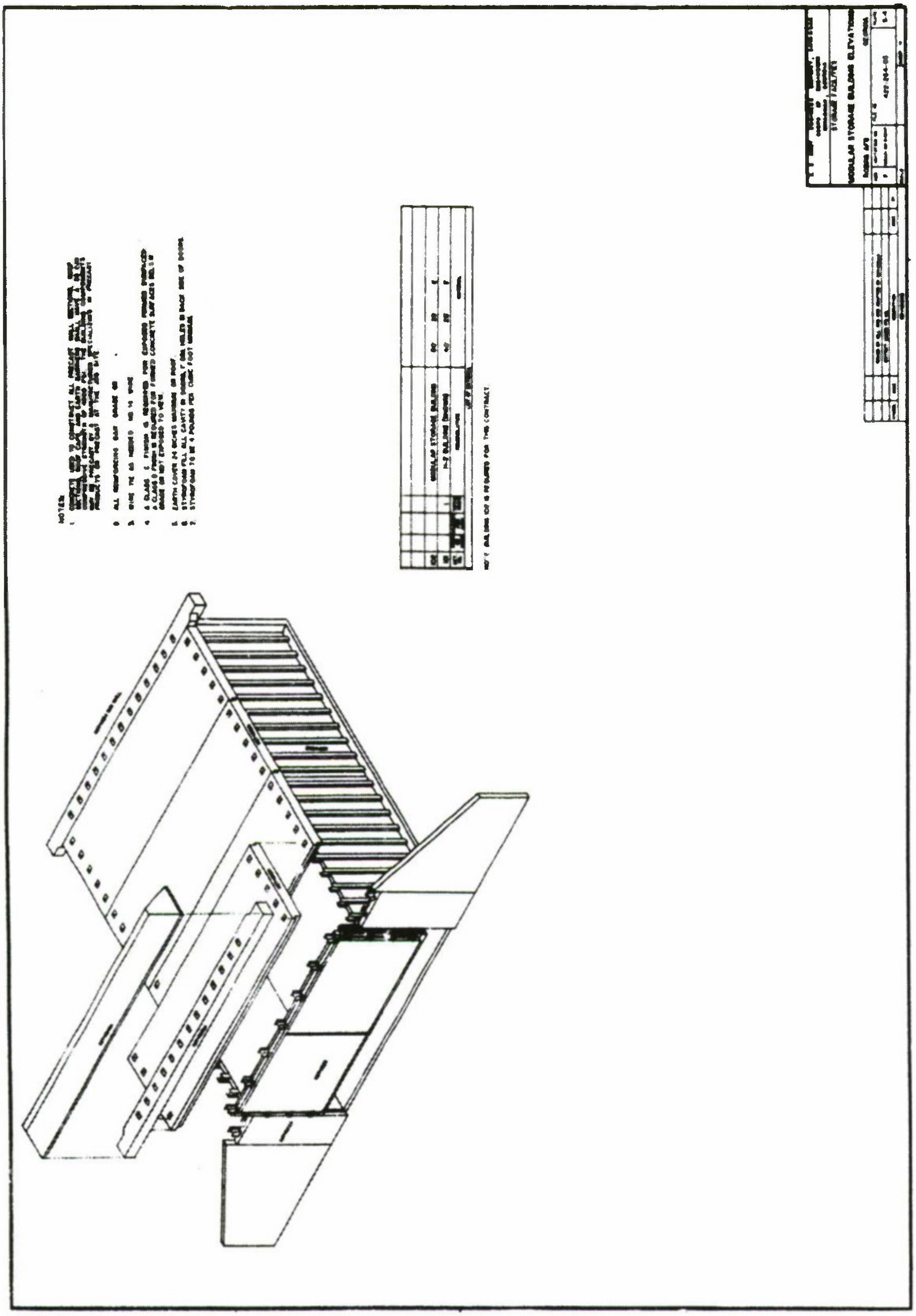

Plate 155: New Mexico Engineering Research Institute (NMERI). Hayman Igloo, Robins Air Force Base, ca.1985. Courtesy of Ken Bell.

In 1981, ESD planned the third and fourth PAVE PAWS, at Eldorado Air Force Station near Goodfellow Air Force Base in western Texas and at Robins. These two radars were under construction in the middle 1980s and were operational in 1986 (Robins) (see Volume I, Plate 117) and 1987 (Eldorado). Both radars were significantly more powerful than the first PAVE PAWS near Boston and Sacramento. (Radar designation for the first PAVE PAWS was AN/FPS-115; for the middle 1980s PAVE PAWS, AN/FPS-123.) With completion of the four PAVE PAWS, the number of large phased-array radars involved in space and missile tracking reached seven (beginning with the AN/FPS-85 at Eglin). Construction of the radar continued, however. The Air Force erected replacement radars for the long-range tracking facilities of the Ballistic Missile Early Warning System (BMEWS). Construction for the BMEWS large phased-array radars overlapped construction of the Robins and Eldorado PAVE PAWS. The BMEWS radars were operational in the late 1980s into 2000 at Thule, Greenland; Fylingdales Moor, Britain; and, Clear, Alaska. The entire radar system was one discussed in the Antiballistic Missile (ABM) Treaty of 1972 (see Volume I, Part I) and in 2002 was under consideration as a major component of the National Ballistic Missile shield. The radar at Robins was to replace that at Eglin, but from the beginning the Robins PAVE PAWS manifested serious interference problems with runway operations at the installation. Both the Robins and Eldorado PAVE PAWS were also in violation of specific wording in the ABM treaty, and in 1995 AFSPC took these two facilities off line. The equipment from the Eldorado radar went to Clear, Alaska, for construction needs at that site, while the radar in Georgia remained in War Readiness Materiel (WRM [warm]) storage. The large phased-array radar program was a complex one, active for more than 40 years of the Cold War period (see Volume I, Part IV).

Key Associated Architects and Engineers

Major architects and engineers associated with building programs at Robins Air Force Base include those for the Special AMC Warehouse and the SAC alert program, and, for the most part, are discussed in Volume I or in other chapters of Volume II, as noted:

- Ammann & Whitney, of New York (Volume I, Part III);
- Black & Veatch, of Kansas (Volume II, Chapter 4);
- Leo A. Daly, of Omaha (Volume II, Chapter 4);
- Ganteaume & McMullen, of Boston;
- Giffels & Rossetti, of Detroit;
- Holabird, Root & Burgee, of Chicago (Volume I, Parts III and IV);
- L.P. Kooken, of Baltimore (Volume I, Part II);
- Fred N. Severud, of New York (Volume II, Chapter 4); and,
- J. Gordon Turnbull, of Cleveland (Volume I, Part III).

Ganteaume & McMullen

Research to date on the firm of Ganteaume & McMullen is limited. Ganteaume & McMullen handled the missile run-up and service shops for the Hound Dog and Quail weapons system, and are assumed to have also designed related types of infrastructure for the American military. Related commissions, however, are undetermined.

Giffels & Rossetti

Giffels & Rossetti began as an engineering firm in 1925 in Detroit, working under the name of Giffels & Vallet by World War II.[59] In that period, the firm, in association with architect L. Rossetti, executed major industrial commissions for the Army, including multiple plants. The work of Giffels & Vallet and Rossetti paralleled that of Albert Kahn and J. Gordon Turnbull in this regard. Giffels &

Vallet was also responsible for the standard Army munitions igloo built at many installations across the United States in the early 1940s. During 1945-1947, Giffels & Vallet, again in association with L. Rossetti, designed Electronics Park for General Electric, a major R&D facility in Syracuse, New York. The Cambridge Research Laboratories, in planning their move from downtown Boston to Hanscom Field, cited Electronics Park as a model for electronics research facilities within ARDC. In 1949, Air Materiel Command had also set up a Test Operations Building at Electronics Park for research toward improved air defense command posts. During the 1950s, Giffels & Vallet continued to take on big contracts for industry and to be associated with the Air Force. In 1951-1952, the firm designed a manufacturing plant for automobile bodies in Gary, Indiana.[60] In 1954, the air installations (civil engineering) unit of Headquarters Air Force hired Giffels & Vallet to execute one of the first sets of definitive drawings for the service, with a second contract to update existing standard drawings in 1956.[61] (The earliest firm handling this type of assignment appears to have been Mills & Petticord, followed by others over time. Although the firm hired for the definitives contract typically entered its name in all title blocks for standard buildings across the Air Force, responsibility was for producing an updated set of uniform drawings, not for the design of structures.) By 1958, Giffels & Vallet (in association with Rossetti) became Giffels & Rossetti. The firm continued to execute multiple major Air Force assignments. That year, the firm not only designed the composite structures for SAC's tenant alert missions (the operations, industrial, and warehouse buildings), but also undertook a project for Headquarters Air Force to develop a manual on radioactive fallout protection—applicable to all Air Force bases. The study of fallout protection additionally extended to Aircraft Control & Warning (AC&W) radar sites.[62] In 1960, Giffels & Rossetti also designed prefabricated structures for the Air Force and had the contract for a servicewide corrosion control shelter. By the early 1970s, Giffels & Rossetti had split into two firms, those of Giffels Associates and Rossetti Associates. Both firms still exist today in greater Detroit and are active, award-winning firms.

---

[1] William P. Head, Diane H. Truluck, Dean Corey, Christine McLeod, and Richard W. Iobst, *Time Capsule: A Chronology of the Role of the Warner Robins Air Logistics Center and Robins Air Force Base, Georgia, in World History, 1935-1995* (Robins Air Force Base: Office of History, Air Force Materiel Command, Fall 1996), 4, 12, 14-16.

[2] The reader can trace the broad patterns of lineage for the installation in Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). The Robins chapter includes the dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base. Mueller does not include the sequence of base names in the Robins chapter. This information is also slightly incorrect in an official Robins history: Charles W. Grindstaff, *War Baby of the South 1940-1945: Robins Field, Georgia* (Robins Air Force Base: Office of History, Air Force Logistics Command, September 1988), 2-14. The reader should refer to Head, Truluck, Corey, McLeod, and Iobst, *Time Capsule*, 1996, *passim*, for the lineage of base names.

[3] Grindstaff, *War Baby of the South 1940-1945*, September 1988, 2-14.

[4] *Ibid*, 16-17.

[5] Fred Carey, Ellen Ehrenhart, Barry Greenhouse, Harriet Kaplan, Darlene Roth, Eva Santorini, and Catherine Wilson-Martin, *Cold War Facility Survey and Report Robins Air Force Base*, Draft (Bethesda, Maryland: Potomac-Hudson Engineering, Inc., for Air Force Materiel Command, June 1999), *passim*.

[6] Grindstaff, *War Baby of the South 1940-1945*, 1988, 16-18. Also, drawings for these buildings are housed as microfiche in the civil engineering vault at Robins Air Force Base. As is very often the case, the Army's process of handling construction obscures the originating architects for some of the key structures. At Robins, the firm assigned the supervisory contract, or the firm responsible for the most recent updating of the drawings set, is sometimes the one included in the title blocks (for example, Graham, Anderson, Probst & White, of Chicago, for the Airplane Repair Building), rather than the originating architects.

[7] Mueller, *Active Air Force Bases*, 1989, 503.

---

[8] Grindstaff, *War Baby of the South 1940-1945*, 1988, ii-iii.
[9] *Ibid*, 45-70.
[10] Woodford Agee Heflin (ed), *The United States Air Force Dictionary* (Princeton, New Jersey: D. Van Nostrand Company, Inc., ca.1954, 122 and 333.
[11] Mueller, *Active Air Force Bases*, 1989, 503.
[12] Head, Truluck, Corey, McLeod, and Iobst, *Time Capsule*, 1996, 106.
[13] Karen J. Weitze, *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970*, Holloman Air Force Base Cultural Resources Publication No. 5 (Plano, Texas: Geo-Marine, Inc., for Air Combat Command, November 1997), 38-40, 52-53, 59-62, 66-67.
[14] Air Materiel Command, *History of Warner Robins Air Materiel Area 1 January – 30 June 1954*, 1-8.
[15] Air Installations Office, "Plan for Enclosing North End of Building No. 105 and Replacing Gypsum Siding on buildings Nos. 105 and 116 with Corregated [*sic*] Metal," 8 July 1949; Installations Office, "Modify Building 116 for Packing & Crating Shop," 4 May 1956; and, Installations Division WRAMA, "Bldg. NR. S-602," undated.
[16] Head, Truluck, Corey, McLeod, and Iobst, *Time Capsule*, 1996, 112.
[17] Radar designations contain encoding that identifies the equipment in detail. The "AN" is a joint military designation for "Army-Navy" found in all radar and similar equipment. The final three letters reference the deployment, type, and mission of the equipment. In "APA" the "A" indicates "airborne" (equipment installed and operated from an aircraft), while "P" indicates "radar." The final letter, "A" is of unknown meaning. In "APN," the "A" and "P" are followed by "N," indicating "navigational aid." It is possible that the references to "AN/APA-54" and "AN/APN-54A" in Head, Truluck, Corey, McLeod, and Iobst, *Time Capsule*, 1996, 118, actually are to the AN/APN-54 and the AN/APN-54A, and that "ANA" is an error. However, some radar and related equipment designations of the early Cold War are difficult to decipher today due to early obsolescence of the electronics type, and subsequently a disappearance of the terminology.
[18] Head, Truluck, Corey, McLeod, and Iobst, *Time Capsule*, 1996, 113-127; *History of Warner Robins Air Materiel Area 1 January – 30 June 1954*, 8, 18.
[19] Air Materiel Command, *History of Warner Robins Air Materiel Area 1 January – 30 June 1953*, 2-3, and, supplement ("WRAMA's Participation in the Atomic Energy Program").
[20] Air Materiel Command: *History of Warner Robins Air Materiel Area 1 January – 30 June 1955*, 13-14, and, *History of the Warner Robins Air Materiel Area 1 July – 31 December 1955*, 27-30. For a discussion of experimental runway construction during the early and middle 1950s see Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 92-97.
[21] Patchen & Zimmerman, "Hangar, Maintenance Shop and Supply Shop," drawing 39-01-01, 24 November 1952. The drawing is the first in the series leading to the widely built Strobel & Salzman readiness maintenance hangar of 1953 and the Kuljian Corporation readiness maintenance hangar of 1955. Originating architectural firm is unresearched, but may be Mills & Petticord of Washington, D.C., who were responsible for a hangar in this series in 1951. See Karen J. Weitze, *Cold War Infrastructure for Air Defense; The Fighter and Command Missions* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 63-71.
[22] L.P. Kooken, "Special AMC Warehouse," drawing 33-02-58, 29 April 1952, adapted for Robins Air Force Base 12 September 1952.
[23] *History of Warner Robins Air Materiel Area 1 July – 31 December 1955*, 8-9. The Air Force defined the "beneficial occupancy date" as that time when a building was sufficiently finished to allow personnel to begin setting up their mission on the premises.
[24] *History of Warner Robins Air Materiel Area 1 July – 31 December 1955*, 9-15.
[25] *Ibid*, 15-25.
[26] Ammann & Whitney, "Special AMC Warehouses Robins Air Force Base Roof Repairs," 24 January 1957.
[27] *History of Warner Robins Air Materiel Area 1 July – 31 December 1955*, 27.
[28] *History of Warner Robins Air Materiel Area 1 January – 30 June 1955*, 14.
[29] Paul W. Stephens, Colonel, Deputy Chief, Air Installations Division, Air Materiel Command, Headquarters, Wright-Patterson Air Force Base, "Status of Architect-Engineer Contracts," memorandum to the Director of Installations, Headquarters United States Air Force, 10 September 1952, in Record Group 341, Entry 494, Box 280, File "Contracts August-December 1952," National Archives II, Maryland.
[30] Air Materiel Command (Robert W. Barnwell and Lewis J. Carey), *History of Warner Robins Air Materiel Area 1 January – 30 June 1956*, 3.

[31] *Ibid*, 4.
[32] *Ibid*, 5; Head, Truluck, Corey, McLeod, and lobst, *Time Capsule*, 1996, 123, 159.
[33] Air Materiel Command (Robert W. Barnwell and Patillo A. Finlayson), *History of Warner Robins Air Materiel Area 1 July – 31 December 1956*, 33-38.
[34] Head, Truluck, Corey, McLeod, and Iobst, *Time Capsule*, 1996, 318.
[35] Air Materiel Command, *History of Warner Robins Air Materiel Area 1 July – 31 December 1958*, 49.
[36] Air Materiel Command (Robert W. Barnwell and P. A. Finlayson), *History of Warner Robins Air Materiel Area 1 July – 31 December 1957*, 36-36-37, 47-48.
[37] Head, Truluck, Corey, McLeod, and Iobst, *Time Capsule*, 1996, 159-160.
[38] Air Materiel Command (Robert W. Barnwell and P.A. Finlayson), *History of Warner Robins Air Materiel Area 1 January – 30 June 1958*, 15-17; Directorate of Installations, Headquarters United States Air Force, "Robins Air Force Base," Master Plan, 1 October 1957.
[39] *History of Warner Robins Air Materiel Area 1 July – 31 December 1958*, 16-35.
[40] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1960*, volume 8, 51-52.
[41] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1963*, volume 2, 45.
[42] Giffels & Rossetti, "Corrosion Control Facility, Covered," drawing AW 39-10-83, 16 November 1960, adapted for Robins Air Force Base by Jones & Associates in June 1964.
[43] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1960*, volume 8, 37.
[44] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1961*, volume 5, 38.
[45] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1964*, volume 5, 37.
[46] Edwards & Rosser, Inc., "Additions to and Alterations of Aircraft Protective Coating Facility," July-September 1974.
[47] Head, Truluck, Corey, McLeod, and Iobst, *Time Capsule*, 1996, 355.
[48] *Ibid*, 168-171, 176-177, 182, 187, 193-195, 197, 199, 212, and 221; Air Materiel Command (Robert W. Barnwell), *History of Warner Robins Air Materiel Area 1 July 1961 – 30 June 1962*, 14.
[49] Air Materiel Command, *History of Warner Robins Air Materiel Area 1 July 1960 – 30 June 1961*, 19-20, 47-50.
[50] Wayne O. Mattson and Martyn D. Tagg, *"We Develop Missiles, Not Air!": The Legacy of Early Missile, Rocket, Instrumentation, and Aeromedical Research Development at Holloman Air Force Base*, Holloman Air Force Base Cultural Resources Publication No. 2 (Holloman Air Force Base: Air Combat Command, June 1995), 57-67.
[51] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 258.
[52] Headquarters United States Air Force: *History of the Directorate of Civil Engineering 1 July – 31 December 1970*, volume 3, 117, 123; and, *History of the Directorate of Civil Engineering 1 January – 30 June 1971*, volume 3, part 1, 152-153.
[53] Head, Truluck, Corey, McLeod, and lobst, *Time Capsule*, 1996, 197, 200, 209, 223, 230, 253, and 255.
[54] *Ibid*, 222, 229, 245, 259, 260, 280, 287, 288, 294, 305, 309, 327, 331, 332, 334, and 344.
[55] *Ibid*, 342, 353, 525, 576, and 578; James Dao, "Much-Maligned B-1 Bomber Proves Hard to Kill," *New York Times*, 1 August 2001.
[56] Douglas C. McChristian and Jerome A. Greene, *Arsenal of the Cold War: A Survey of Potentially Significant Facilities on Property Administered by Hill Air Force Base, Utah* (Denver: National Park Service, for Air Force Materiel Command, December 1999), 401-402; the New Mexico Engineering Research Institute, "Modular Storage Building Elevations Robins AFB Georgia [H-2 Building]," undated.
[57] Karen J. Weitze, oral interview with Terry Smith, range manager, UTTR, 31 October 2000.
[58] The equipment coding breaks down as: "F" fixed, "P" radar, and "S" detection.
[59] Although multiple cross references to Giffels Associates and Rossetti Associates exist on the internet, the author has not located web sites discussing the companies' intertwined history.
[60] "Flexible Plant for Automobile Bodies," *Architectural Record* 111, 2 (February 1952): 164-169.

[61] Headquarters United States Air Force, *History of the Assistant Chief of Staff, Installations 1 January – 30 June 1956*, volume 7, 54.
[62] Headquarters United States Air Force: *History of the Directorate of Installations 1 January – 30 June 1958*, volume 8, 65; and, *History of the Directorate of Installations 1 July – 31 December 1958*, volume 7, 84.

Chapter 12: Rome Research Site

Historic Missions of the Cold War

The Rome Research Site is one of several Air Force responsibilities remaining at the former Griffiss Air Force Base. In 1995, the installation completed the process of closure, with its infrastructure continuing to transition to a business park in 2000. The Rome Research Site supports the Air Force Research Laboratory (AFRL) and sustains a mission focused on sensor and information technology research and development (R&D). Historically, Griffiss served as both a depot for Air Materiel Command and its follow-on, Air Force Logistics Command (AFLC), and as a research installation. The Army Air Forces established the Rome Air Depot in late 1941. Materiel Command / Air Technical Service Command assigned the depot repair and maintenance missions for aircraft engines. Beginning in 1942-1943, the base anchored the Rome Air Materiel Area (AMA), one of 12 major air materiel areas at the end of World War II. In 1946, the number of AMAs shrank to 10 in the continental United States, with further consolidation to seven by the middle of 1947. Air Materiel Command eliminated the Rome AMA (ROAMA) in the downsizing and, during 1947-1948, Rome Army Air Field served as a holding station for German scientists in the Paperclip program. The installation took on a more defined Cold War configuration in 1948. At the outset of that year, the airfield and former AMA became Rome Air Force Base, almost immediately renamed Griffiss.

Air Materiel Command initially hoped to move the personnel and functions of its Watson Laboratories Cambridge Field Station in Boston to Griffiss, augmenting the base primarily for electronics research and testing. In April 1948, just as Rome concluded its Paperclip role, Griffiss Air Force Base began its transition toward an electronics mission. In November, the Data Utilization Laboratory (formerly, the Visual Design Laboratory) of the Cambridge Field Station moved to Griffiss. During 1949 and 1950, however, decisions to relocate the remaining individual Cambridge laboratories to Rome stalled. Air Materiel Command selected Hanscom Field near Boston as a permanent home for most of the Cambridge personnel, simultaneously transferring the technical library and staff from the Watson Laboratories in New Jersey to Rome. Watson Laboratories personnel began their relocation to Rome in November 1950. On 12 June 1951, Griffiss became home to the Rome Air Development Center (RADC) under Air Research and Development Command (ARDC). Also in late 1951, Air Materiel Command reinstated a logistics function at the installation, bringing back the mission through the designation of a special depot for ground communication and electronics equipment. Until 1955, the depot at Griffiss fell under the larger jurisdiction of the Middletown AMA in Pennsylvania (Olmsted Air Force Base). Between January 1955 and April 1967, the Rome AMA (ROAMA) operated in a primary logistics role for Air Materiel Command and its follow-on Air Force Logistics Command (AFLC). In July 1954, Air Materiel Command became the base host, superceding ARDC. Air Materiel Command / AFLC sustained this position until mid-1970.

A dual set of major missions, then, characterized Griffiss during the Cold War years of 1945 to 1967—tied to both halves of today's Air Force Materiel Command. (Extant at the former installation today are links only to the electronics mission of the RADC and its successor laboratories.) For the greater part of its existence, Rome's depot function also concentrated on electronics equipment, and in mid-1958 Griffiss additionally became the headquarters location for the Ground Electronics Engineering Installation Agency (GEEIA). GEEIA, with important subposts at other AFLC bases, engineered and installed ground communications equipment worldwide (see Volume I, Parts II and IV). The RADC was tiered under ARDC until July 1960, with a radar electronics mission and a key role in the development of sequential air defense systems (along with the Cambridge Research Center). The latter mission tied the RADC intimately to R&D for Air Defense Command (ADC).

The RADC sustained multiple missions for the unfolding generations of air defense command posts:

- from those of the late 1940s (the Air Defense Control Centers [ADCCs] and the Air Defense Direction Centers [ADDCs]),
- to the Semi-Automatic Ground Environment (SAGE) of the late 1950s into the early 1980s,
- to the complementary Back-Up Interceptor Control (BUIC) network of the 1960s forward,
- to today's Region Operations Control Center (ROCC) of the Joint Surveillance System (JSS).

In 2000, the ROCC of 1982 (designated a Sector Operations Control Center [SOCC] after 1987) monitors the Northeast Air Defense Sector (NEADS), a geographic area spanning 22 states.

The air defense mission at Griffiss, through the work of the laboratories as well as at base and off-site locations connected to the installation, was complex. A notable non-research element of the air defense mission included the presence of a double fighter-interceptor squadron (FIS) from late 1950 through July 1987. The air defense command post lineage is also impressive. Within the continental United States, Griffiss featured one of 16 ADCCs and one of three combination Combat and Direction Centers for SAGE, located off site at Hancock Field in Syracuse. Today, the SOCC on the former Griffiss Air Force Base is one of four ROCCs in the nation. Within the RADC, personnel worked on multiple air defense radars throughout the Cold War decades and were involved in each of the major systems as they went through research, development, testing, and evaluation. Annex radar and electronics communications test sites tied to the RADC were numerous. The RADC fell under the jurisdiction of the Air Force Command and Control Development Division (AFCCDD) at Hanscom Air Force Base in 1960, accompanying a parallel hierarchical move for the Cambridge Research Center (subsequently, Cambridge Research Laboratories) (see Volume I, Part II). The RADC and the Cambridge Research Laboratories both transferred to the Electronic Systems Division (ESD) under Air Force Systems Command (AFSC), the successor to ARDC, in 1961. ESD was the follow-on to the AFCCDD and was also located at Hanscom. From 1962 until 2000, more organizational changes occurred, with periods when the RADC was subsumed under ESD at Hanscom, and periods when the center functioned as a direct unit within AFSC. In 1976, AFSC separated the electronics and geophysics halves of the Cambridge Research Laboratories, attaching the electronics laboratories at Hanscom to the RADC at Griffiss (see Volume II, Chapter 5). The RADC maintained major laboratories physically at the Boston-area base. Consolidation into four super laboratories within AFSC, and later Air Force Materiel Command, led to the Rome Research Site's placement within the Air Force Research Laboratory in 1997.

One other important Cold War mission existed at Griffiss during the Cold War: a Strategic Air Command (SAC) alert wing as of August 1958. The 4039th Strategic Wing was a tenant at the base, occupying a major site at the installation. Buildings included the composite structures usually found where SAC was a tenant, in addition to the alert readiness crew quarters (molehole) and weapons support facilities for the Hound Dog – Quail system (see Volume I, Part IV). SAC discontinued the 4039th Strategic Wing in 1963, and activated the 416th Bombardment Wing at the base for the remainder of the conflict. In 1970, SAC became the base host, superceding AFLC. Thereafter, a SAC mission dominated the development of Griffiss. SAC sequentially equipped the 416th Bombardment Wing with the Short-Range Attack Missile (SRAM) and the Air-Launched Cruise Missile (ALCM) in the middle 1970s and early 1980s, respectively.

Primary Missions

The primary Cold War missions at Griffiss Air Force Base were those of Air Materiel Command / AFLC through the installation's role as a depot (1945-1947, 1951-1967), ARDC / AFSC for the Rome laboratories and RADC (1948-1991), and SAC (both as a tenant from 1958 to 1970, and, as

installation host from July 1970 to base closure). Only the RADC and laboratory missions are bulleted below. These missions included research, development, testing, and evaluation for:

- multigenerational radars;
- aircraft navigation systems;
- air defense and tactical air control electronics display equipment and status boards;
- sophisticated communications;
- tracking and guidance technologies;
- electronic warfare equipment;
- surveillance technologies;
- security sensor systems; and,
- automated foreign language translation devices.

The RADC and Rome laboratories also conducted:

- stores testing to evaluate antenna patterns and radar signatures for fighter aircraft;
- large-aircraft antenna pattern testing; and,
- electronic reliability analysis and testing.

The center and its laboratories sustained:

- major program responsibilities for SAGE, BUIC, and the JSS.

Tenant Organization Missions

Historic tenant missions of note at Griffiss included those of ADC and SAC:

- FIS alert from late 1950 to the end of the Cold War;
- an off-site ADCC at Hancock Field in Syracuse from 1951 to late 1958;
- final testing for SAGE at the combined Combat and Direction Centers at Hancock Field in 1956-1958;
- SAGE Combat and Direction Centers at Hancock Field (the very first SAGE command post operational nationwide) from 1958 through 1982 (one of the final six SAGE centers remaining on line at the end of the program);
- an ROCC (SOCC) for the JSS from 1982 forward; and,
- SAC alert from 1958 into the early 1960s, followed by a major SAC bombardment wing on site throughout the remainder of the Cold War.

Chronology

The Rome Research Site is situated on the former Griffiss Air Force Base. The installation originated during early World War II as the Rome Air Depot.[1] Construction at the upstate New York site began in August 1941, with the base minimally operational early the next year. The first plane landed at the airfield in February 1942, while the first troops arrived in March.[2] Infrastructure included four standard Army Air Corps steel maintenance hangars of late 1930s design (an Airplane Repair Building) (Building 101), configured as two pair of hangar bays bracketing a complex of shops. Also prominent at the installation was an Operations – Transport Squadron and Flight Test Hangar (Building 100). Albert Kahn of Detroit had designed the precursor for the Operations – Transport Squadron and Flight Test Hangar in 1940 (formally known as a Transport Squadron Hangar). In 1941, a group of affiliated professionals, the Air Depot Architects Engineers, improved Kahn's

Transport Squadron Hangar. Fred N. Severud, a major consulting engineer in New York City, was the primary contributor to the Air Depot Architects Engineers' efforts and was the individual responsible for the advanced hangar. Severud went on to design a very early B-36 wing hangar (nose dock) derived from the Operations – Transport Squadron and Flight Test Hangar in 1944-1945 (see Volume I, Plate 5). The Air Corps and Army Air Forces erected combinations of the Airplane Repair Building and the Transport Squadron Hangar / Operations – Transport Squadron and Flight Test Hangar at most depots in the continental United States from 1937 into 1943 (Volume II, Chapters 4, 6, 7, 10, 11, 13 and 14). These two hangars would become important Cold War facilities at all installations where they existed.

The War Department also awarded the Air Depot Architects Engineers the overall contract for master planning the depot in Rome, in mid-1941.[3] By the close of 1943, the base had four supply warehouses with rail spurs, two mobile-depot group areas, the Airplane Repair Building, the Operations – Transport Squadron and Flight Test Hangar, a cluster of permanent-construction engine repair, test, and storage buildings, several small Quartermaster warehouses, and a segregated chemical warfare warehouse (Buildings 1, 2, 7, 8, 9, 10, 14, 20, 23, 100, 101, 102, 104, 105, 106, 108, 112, 115, 119, 120, 134, 220, 221, 301, 303, 308, 310, and 316).[4] Engineers configured three reinforced concrete runways in a triangular pattern typical of Army Air Forces installations during the early 1940s, each 150 feet wide and of 4,523-, 4,526-, and 6,282-foot lengths.[5] Alternate early names for the Rome Air Depot were Rome Army Air Base, Rome Army Air Field, the Rome Air Depot Control Area, and, in July 1946, the Rome AMA. During World War II, the Rome Air Depot provided aircraft engine maintenance and repair under Materiel Command / Air Technical Service Command. Base personnel also trained air depot groups in engine repair. Command assignment transitioned to Air Materiel Command in 1946. The Rome Air Depot maintained connections to several off-site airfields in the region between 1942 and 1946, including management responsibility for Bedford Army Air Field (the future Hanscom Air Force Base) northwest of Boston from mid-October 1944 until July 1946[6]—a period during which Bedford Field was in a general hiatus, with the critical exception of air defense activities through I Fighter Command and the Massachusetts Institute of Technology (MIT) (see Volume II, Chapter 5).

Following the victory in Europe, activities at the Rome Air Depot wound down during 1945. In May, the base became a storage site for aircraft engines. The Army Air Forces reduced the workforce at the installation after the autumn victory in Japan. During 1946 and 1947, Air Materiel Command closed many of the buildings at the depot, declaring others surplus and selling 19 buildings in January 1947.[7] Simultaneously, the command concluded its AMA mission at the base (see Volume I, Part II). In March 1947, a master plan of the base illustrated a core area of permanent buildings—the two major hangars of World War II, with six engine repair facilities and two pair of depot supply warehouses directly behind them off the flightline. With the exception of about five other small buildings at Rome Army Air Field, woodframe temporaries comprised the larger part of the dormant base. By this date also, planners described the Rome runway system as "VVHB" (very, very heavy bomber) -capable, an indication that engineers interpreted the 6,282-foot reinforced concrete runway of 1941 as able to land the B-36 in the short term[8] (see Volume I, Part II). From spring 1947 until about a year later, activities at Rome were minimal, but did include a unique function for Air Materiel Command. During the 12-month period, Air Materiel Command used the base as a holding location for German scientists and engineers whom the command considered excess. At Rome, men originally brought to the United States for assignment within Air Materiel Command under Project Paperclip awaited transfer to private industry through the Department of Commerce, to other military services, or for permanent return to Germany (see Volume I, Part III).

In March 1947, Headquarters Air Materiel Command at Wright Field planned to send 37 Paperclippers to Rome, with another 13 to follow. The command set the quota of Paperclippers to be

housed at Rome Army Air Field at 50 men, considering their isolation a security matter. Most of the Paperclippers passed through upstate New York during the first half of 1947, and by the end of the year only a handful of men were still in residence. In mid-April 1947, the base officers' club furnished housing and messing for 20 Paperclippers.[9] (The designated housing was of some irony as there was also the physical remnants of a Prisoner of War [POW] camp on base [see Plate 163].) Among the Germans immigrating to the United States through Project Paperclip generally, the name for Paperclip was Project Icebox. The men feared that they would be put on ice and returned to Germany once they divulged desired information. The channeling nexus at Rome partially substantiated both their nickname for Paperclip and their uneasiness (see Volume I, Part III). Paperclippers documented as having passed through Rome included Hans Berkner, Friedrich Bielitz, Hans Bielstein, *Hans Brede, Walter Brisken, *Joachim Carl, *Eugen Duerrwaechter, Willi Elias, *Hermann Ehrhardt, *Wilhelm Ernsthausen, *Heinz Gartmann, *Otto Harr, *Hans Heinrich, Dr. Siegfried Hoh and his wife, Bernhard Hohmann, Josef Hubert, Helgo Jahnke, *Heinz Jung, Heinz Moellmann, Erwin Neumann, *Carl Nutz, Rudolf Opitz, *Heinrich Reindorf, *Georg Rickhey, Franz Rinecker, *Hans Ruef, *Franz Scheubel, Ernst Sielaff, Adolf Strott, *Herbert Timm, Friedrich Wazelt, and *Wilhelm Westphal. (Those individuals with asterisks next to their names were returned to Germany.) During 1947-1948, too, Rome Army Air Field had charge of at least one Paperclipper placed in private industry in upstate New York, H. Nerwin. Mr. Nerwin subsequently worked for Graflex, Inc., in Rochester.[10] The actual fate for many Paperclippers who spent months in Rome during 1947-1948 was split, with not all men sent home or moved into American industry. Fourteen men are again on the lists of Paperclip personnel working at Wright-Patterson Air Force Base in Ohio by mid-1948. The final five still in Rome in early 1948—Bielitz, Bielstein, Elias, Rinecker, and Strott—are among those identified as having been returned to Wright-Patterson.[11]

In about mid-1946, Air Materiel Command explicitly evaluated Rome Army Air Field as a probable site for an electronics subdivision to support a future Air Engineering Development Center (AEDC) (see Volume I, Parts II and III, and Volume II, Chapters 1 and 5). While locational surveys were underway for an AEDC—which would become the Arnold Engineering Development Center at Tullahoma, Tennessee, in the early 1950s—the command evaluated alternate ideas for the development of its electronics units at Wright Field, the Watson Laboratories in New Jersey, and the Cambridge Field Station of the Watson Laboratories in Boston. The command understood that it needed to address its electronics needs under three conditions—conditions that were both short-term and long-term, and that overlapped each other:

- if an AEDC achieved fruition and included a major electronics subcomponent;
- while construction for an AEDC was in progress, with an electronics component; and,
- if Congress did not fund an AEDC (or, if the center had no electronics component).

For example, at Wright Field, Air Materiel Command noted that whether or not an AEDC went forward with an electronics component, the installation required an all-wood radar test building free from electronic noise (a commission of July 1947—see Volume II, Chapter 14). Air Materiel Command formulated its final plans based on the assumption that a minimum workforce of 2,000 electronics specialists drawn from Wright Field, the Watson Laboratories, and the Cambridge Field Station would physically relocate to an AEDC.

In evaluating the Watson Laboratories, Air Materiel Command planned to divide up its activities and personnel between an AEDC (if built) and Wright Field (moving the remaining personnel to Dayton), if the Army Air Forces built an AEDC with an electronics mission. Should there be no AEDC (with an electronics component) and should Eglin Field in Florida (desired for the availability of its ranges—to host off-site radar test units) not be subsumed under Air Materiel Command, then the command intended to consolidate an electronics squadron at Olmsted Field near Harrisburg,

Pennsylvania (the Middletown AMA). The second variation included the Watson Laboratories and its Cambridge Field Station, and an expansion of the physical facilities in New Jersey and Boston. Under that scenario, the command planned to build a new airfield just north of the Watson Laboratories in Red Bank, New Jersey. Without a major electronics buildup within an AEDC, Air Materiel Command knew that substantial land holdings were necessary for test sites, and possibly for a new electronics installation. In its 1946 study, Air Materiel Command suggested acquisition of either Camp Charles Wood or Fort Dix (both in New Jersey), Rome Army Air Field, or Fort Devens (in Massachusetts). The command assumed that it would consolidate the Watson Laboratories and Cambridge Field Station at one of these locations. The authors of the study leaned toward Fort Devens, not the Rome Army Air Field, but noted that Rome was a strong contender.[12] (Other discussions of 1945 had suggested Bedford Army Air Field [the future Hanscom] for an AEDC. See Volume I, Part III.)

The Watson Laboratories were integral to the electronics R&D center that unfolded during the early Cold War at Griffiss. Watson had originated as the Radio Laboratory of the United States Army Signal Corps at what became Fort Monmouth. The laboratory tested early vacuum tubes, radio sets, and radio direction-finding techniques. By the end of the 1920s, a group of electronics laboratories existed at Fort Monmouth, consolidated as the Signal Corps Laboratories. Experimental work in these important technical facilities led to American radar of World War II. At the outset of the 1940s, in response to war needs, the Signal Corps Laboratories had expanded to three new physical sites in the Fort Monmouth area: Camp Coles, Eatontown, and Evans. The four Fort Monmouth laboratory clusters included over 14,500 personnel by the close of 1942. In early 1945, the Army reorganized the New Jersey laboratories in anticipation that the Allies would win the war. The Signal Corps created the Watson Laboratories, pulling together sections from several of the laboratories associated with Fort Monmouth. The Army assigned the Watson Laboratories to its Air Forces under Air Technical Service Command. Personnel at the Watson Laboratories focused their attentions on the development of long-distance radar.[13] With the closure of the MIT Radiation Laboratory in Boston, the Watson Laboratories acquired a major regional adjunct unit—the Cambridge Field Station (primarily composed of former MIT Radiation Laboratory personnel) (see Volume II, Chapter 5).

By mid-1946, the Watson Laboratories and its Cambridge Field Station were working on a variety of electronics problems tied to the development of an effective air defense network for the continental United States. These efforts included ones toward air defense radar. One specific project attempted to integrate the AN/CPS-6 with the World War II Fighter Control Center[14] (see Volume I, Part IV). Other projects included entering radar data from a remote site onto a well-designed plotting board in an air defense command post. This project focused partially on the development of automatic teleplotting relayed to an ADCC. The Watson Laboratories also improved multiple types of three-dimensional information displays required in air defense operations.[15] As decisions moved forward for the permanent location of an electronics R&D center for Air Materiel Command during 1947, the command continued to look at Rome Army Air Field. At that juncture, the command was considering the relocation of the electronics personnel from Watson and the Cambridge Field Station, as well as Watson's geophysics (upper atmosphere and weather) scientists. Rome, New York, offered an Army base:

- for which there were no other immediate plans;
- proximity to established electronics manufacturers in Utica, Syracuse, and Schenectady; and,
- university contracting possibilities through programs at Cornell, Rochester, and Syracuse.

The area also had available off-site locations for anticipated ancillary electronics and radar test stations, in a region that was appropriately hilly and uninhabited.[16] One example of a premier

industry laboratory in the Rome area was General Electric's Electronics Park in Syracuse, a state-of-the-art private research center of the middle 1940s (see Volume I, Part III).

The dilemma of where and how to develop an electronics research center within Air Materiel Command was beginning to pull apart during 1947-1948, however. Many of the scientists working at the Cambridge Field Station in Boston were unwilling to move to Rome, New York. The command next added more Boston area sites to its list of possible permanent locations for an electronics R&D center, including Bedford Field northwest of the city. Nonetheless, after two years of study, Air Materiel Command announced a decision in favor of a Rome relocation in February 1948. The command planned to transfer the whole of the Cambridge Field Station in Boston and the Electronics Flight Test Squadron, 4149th Air Force Base Unit, from Olmsted Air Force Base in Pennsylvania, to Griffiss. An advance party went to Rome immediately, "to serve in a liaison capacity between the Base, installations concerned, and local representatives." Air Materiel Command first shifted the Data Utilization Laboratory of the Cambridge Field Station (the former Visual Design Laboratory) from Boston to Rome. Preparations to relocate this laboratory began in May—just after the Air Force renamed Rome Army Air Field as Griffiss Air Force Base. The first electronics research laboratory to arrive at Griffiss, the Data Utilization Laboratory led by Dr. Robert F. Nicholson, focused its studies on the presentation and accurate use of radar navigation and control information. The Data Utilization Laboratory looked closely at horizontal and vertical plotting boards for air defense filter centers, and for ADC and Tactical Air Command (TAC) control centers. The laboratory also was responsible for designing air control and national defense simulators. For air traffic control, laboratory personnel worked with the Civil Aeronautics Automatic Posting System to create ground and airborne automatic displays. The Data Utilization Laboratory additionally consulted with MIT. Computerized simulators for air traffic control incorporated parameters such as departure time, cruising speed, navigation class, and capacity. Air defense simulators coordinated similar types of information pertinent to time-space paths.[17]

The Data Utilization Laboratory was the smallest of the laboratories at the Cambridge Field Station, staffed at nine scientists in July 1948, and thus the simplest to physically relocate. Air Materiel Command staffed the other laboratories at Cambridge significantly higher: Navigation at 45 men; Communications and Relay, also 45; Special Studies, 20; Antenna, 25; R.F. (Radio Frequency) Components, 48; Electro-Mechanical, 124; and Radar, 41. The Cambridge Field Station Director's Office included 23 personnel. Efforts accelerated toward the Rome move in November, as the command sought to make the change in a manner that least disrupted ongoing research projects. The personnel of the Data Utilization Laboratory physically relocated to Rome at the end of the month and were given facilities in Building 119. Other structures set aside for the electronics mission at Griffiss were Buildings 102, Temporary (T)-103, 104, and T-120. Air Materiel Command planned to transfer the Cambridge laboratories in phases over two years. Moves for the Potentiometer Branch of the Electro-Mechanical Laboratory, the Communications and Relay Laboratory, the R.F. Components Laboratory, the Antenna Laboratory, the Special Studies Laboratory, the Radar Laboratory, the Navigation Laboratory, the Geophysical Directorate, and the remainder of the Electro-Mechanical Laboratory were to follow that of the Data Utilization Laboratory. By the date of the relocation of the Data Utilization Laboratory (November 1948), scientists working at the Cambridge Field Station had become increasingly vocal in their opposition to the transfer, stating that Harvard's and MIT's libraries could not be matched, nor could the industrial contacts within the greater Boston area—notwithstanding the electronics companies based in upstate New York. Estimates of the period suggested that no more than 50 percent of the Cambridge personnel would actually make the move. Of note, even within the Data Utilization Laboratory, five of its nine men had resigned or transferred to other laboratories in Boston rather than relocate to Rome.[18]

During 1949, only the handful of employees from the Data Utilization Laboratory and the advance party representing the Cambridge Field Station were physically at Griffiss, there as elements of the Base Directorate, Research and Development. Among the future employees' concerns were ones for adequate housing in the Rome area. The Air Materiel Command decision to move to Griffiss remained unsettled and local builders were reluctant to speculate on a large-scale housing venture. By mid-year, builders had initiated a 4,000-house development. A number of bureaucratic procedures crept into the mix, with some salaries lower in Rome than in Boston (due to Civil Service mandates), with possible loss of grade level (having the same effect), and with the announcement that should a consolidation occur after the Cambridge Field Station employees transferred to Griffiss, the station personnel would receive lesser consideration in retaining their jobs than individuals already at the base. Especially worried were support personnel, among whom would develop some predictable redundancies as Griffiss, the Watson Laboratories, and the Cambridge Field Station merged. The whole of the situation undermined an effective reorganization of the Cambridge laboratories at the Rome site. Congressional funding for the relocation of the Cambridge Field Station and the Watson Laboratories in New Jersey was also still up in the air, with appropriations anticipated, but not firm, for fiscal year (FY) 1950. As word spread that Air Materiel Command planned to relocate the 45 men of the Communications and Relay Laboratory in late July 1949 (after the turn of the FY of that era), unrest at the Cambridge Field Station became rife and led to an immediate meeting. Upper Air Force commanders, as well as the chiefs of the Cambridge laboratories, attended the convocation. The results were a revision of earlier intentions that called for electronics research centers at both Griffiss and Cambridge, and that involved the scientists more closely in organizational decision making.

1. The Air Force was to maintain a permanent research laboratory in the Cambridge Field Station area for electronics and allied fields.
2. Air Materiel Command would establish a Development Center at Griffiss Air Force Base.
3. Cambridge Field Station was to assist in establishing the Development Center.
4. A committee of men competent in the administration of scientific research were to work out the details of the mission and program of the Cambridge Field Station.[19]

The meeting of mid-1949 led to the formation of a committee to formulate an acceptable approach for the establishment of an Air Force research program in electronics. The committee, in addition to working with the notion of two centers (at Cambridge and Griffiss), was to devise acceptable principles that could govern the relationship between Boston and Rome. The first meeting had included the Assistant Secretary of the Air Force, Eugene M. Zuckert, and Mr. Robert M. Barrett, Chief of the Airborne Antenna Research Branch of Cambridge Field Station's Antenna Laboratory. In 1948, Mr. Barrett had initiated internal efforts at the Cambridge Field Station for the design of a progressive laboratory complex, coordinated with the Graduate School of Architecture at MIT (see Volume I, Part III). The committee, raised to the status of a board, included several Cambridge Field Station laboratory chiefs, and planned to meet on 7 July with Assistant Secretary Zuckert in attendance. Simultaneously, Assistant Secretary Zuckert presented the status of the Cambridge-Rome situation to the Subcommittee of the House Committee on Expenditures in the Executive Department. Generally assumed was a delay in the passage of the needed authorization bill for construction funding of an electronics development center at Griffiss.[20]

While these events unfolded, the Data Utilization Laboratory at Griffiss began its assignment as the core unit for the future electronics center. The 3135th Electronics Squadron had transferred from

Olmsted Air Force Base to Rome in May 1948, redesignated as the 3171st Electronics Research Group in early 1949 and as the 6531st Flight Test Squadron in July 1951.[21] The initial five buildings for the Data Utilization Laboratory clustered behind the Airplane Repair Building (Building 101) of World War II. This core group included three permanent structures and two woodframe temporaries (Plate 156). The large block on which these buildings sat was also the single area featuring a related electronics depot mission during the early 1940s, with the three permanent buildings built for radio repair (Building 102), equipment repair (Building 104), and armament-fire control (Building 119). (Building T-121, also within the complex during World War II, served as a signal supply warehouse.)[22] Immediate preparations at Griffiss during 1950-1951 focused on upgrading runways, taxiways, and aprons, including construction for an ADC FIS alert area. In 1950, workmen widened each of the three World War II reinforced concrete runways by applying a surface treatment on soil cement. At the same time, Griffiss added a taxiway and rectangular apron, improving an existing apron near the mobile-depot area with a two-inch asphaltic overlay on a stone base. During 1950-1951, the installation lengthened its northwest-southeast runway to 7,350 feet through reinforced concrete extensions at each end and also completed the ADC alert apron and taxiway in 1951.[23] ADC possessed a four-pocket Butler alert hangar before the close of the year.[24] The 6531st Flight Test Squadron activated in July 1951, following the formal designation of the RADC in June. The 6531st Flight Test Squadron functioned with a dual purpose, for ADC alert and for coordinated electronics testing for the RADC. Again, the links between electronics R&D at the Cambridge Research Laboratories and the RADC were strong. Both electronics centers were under construction in the early 1950s, at Hanscom and Griffiss. In 1952, the RADC loaned the 6531st Flight Test Squadron to Hanscom Field to support radar and communications testing there until 1954. In that year, Hanscom received its own ADC alert area (featuring a standard four-pocket Strobel & Salzman hangar), while Griffiss simultaneously expanded to an eight-pocket Butler hangar. The 16 fighter aircraft for Hanscom's 1952-1954 testing remained based at Griffiss (see Volume I, Part IV, and, Volume II, Chapter 5).

The Data Utilization Laboratory, physically relocated to Griffiss, continued to report administratively to the Cambridge Field Station during 1949 and 1950. Dr. Nicholson, chief of the laboratory, concentrated efforts on surveillance radar, air intercept control, and air traffic control. While about half of his staff had originally committed to Griffiss in late 1948, in December 1949 he was the sole transferee from Cambridge remaining with the group and had a research laboratory starting over with completely new personnel. Dr. Nicholson brought a unique background to radar and air data communications science. Trained at the Catholic University in Washington, D.C., in electrical engineering and physics, and teaching at that institution for a period, Dr. Nicholson had worked for many years as the director of the Experimental Laboratory of the Fox Film Corporation in New York City. There he had designed and improved sound recording methods. In 1937, he hired as a physicist of visual design for the Signal Corps Laboratory in Washington, D.C., where he researched military photographic equipment. He became a Captain at the Signal Corps Engineering Laboratories at Fort Monmouth in late 1942. At Fort Monmouth, Dr. Nicholson pursued R&D for radar and photographic equipment and was credited for the design of radar display for centralized fire control—a key element for ADC command posts of the Cold War from the ADCCs of the late 1940s to the SAGE Combat Centers of the late 1950s, and for all subsequent centers. Dr. Nicholson moved to the Cambridge Field Station of the Watson Laboratories in February 1946, concentrating on high-speed electronic data systems appropriate to air defense networks and air traffic control.[25]

Dr. Nicholson's work at the Cambridge Field Station in 1946 coincided with the earliest efforts between the Watson Laboratories and ADC toward improvement of data display and the communication of information within the Fighter Control Center of World War II (see Volume I, Part IV). The Cambridge Field Station pursued advanced data display and intercommunications

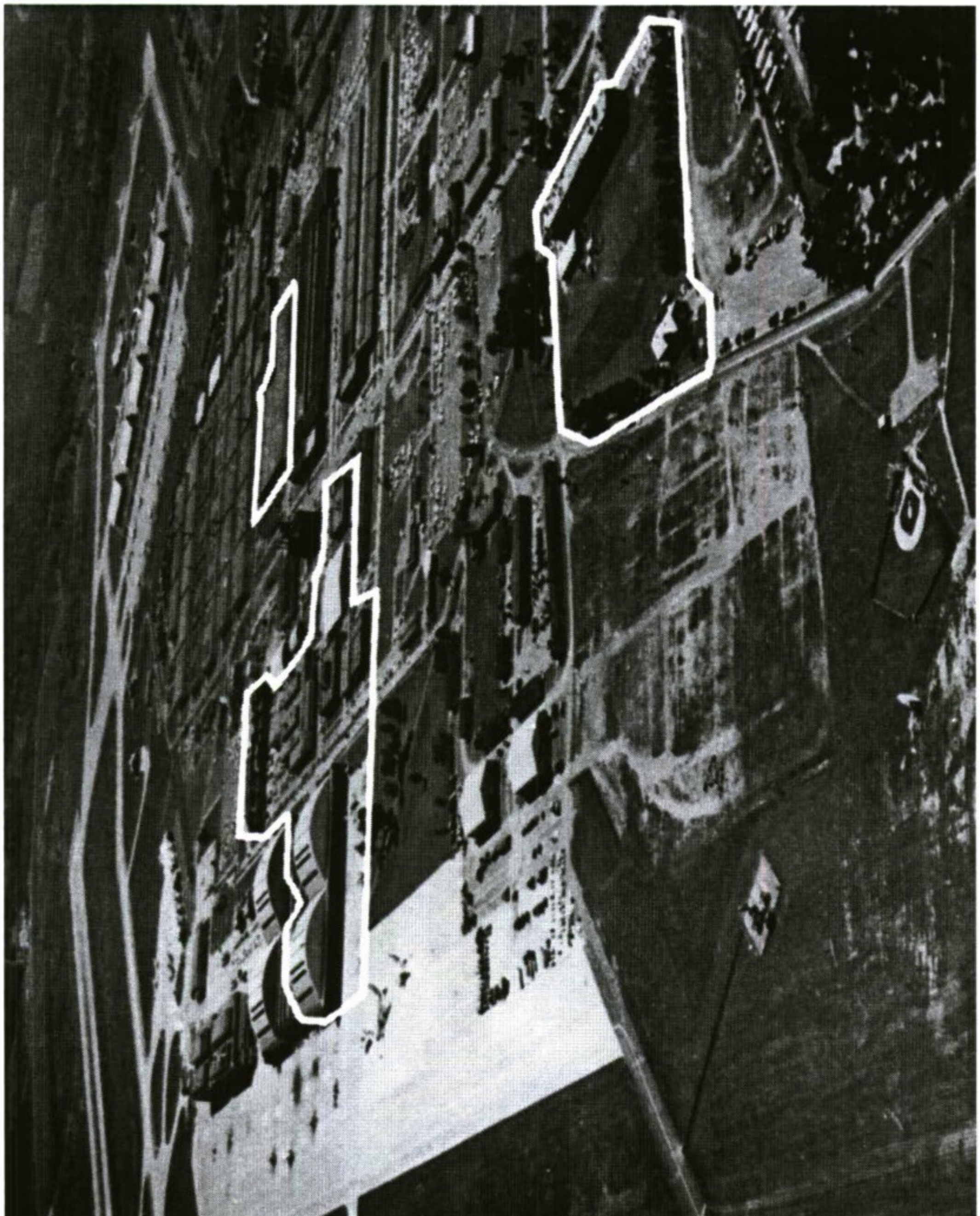

Plate 156: Aerial View of the RADC Areas at Griffiss Air Force Base, ca.1958. Foreground right: Cram & Ferguson, Intelligence and Reconnaissance Laboratory (Building 240), 1952. Middleground left: Reuse of World War II Area (Buildings 100, 102, 104, 106, 112, and 119). Middleground right: L.P. Kooken and Ammann & Whitney, Special AMC Warehouse (Building 3), 1952-1953. Courtesy of the History Office, Rome Research Site, AFRL.

simultaneously with Air Materiel Command's civil engineering involvement in the design for the first Cold War generation of air defense command posts, the ADCCs and ADDCs. Events moved quickly during 1946 into 1951, with the ADCC / ADDC system designed in late 1949 by Holabird, Root & Burgee after two years of coordination between Headquarters Air Materiel Command and Headquarters ADC. The system was under construction during 1949-1952 at most air defense posts. The efforts of the Watson Laboratories, and of Dr. Nicholson in particular, were the very first to improve the operations rooms (war rooms) of the air defense command posts, automating data transmission and display, as well as addressing such concerns as the accuracy and speed of human voice and statically presented information from point to point. While air defense experimentation associated with Hanscom Field dates to 1944-1945, Cold War R&D toward an air defense network was minimal at Hanscom Field until 1949 (and was associated with MIT at that location). Air Materiel Command did not set up a simulated control center at Hanscom until 1951-1952, coincident with the construction of MIT's Lincoln Laboratory on base. During 1951, MIT and the Cambridge Field Station (soon, Cambridge Research Laboratories) established a mock command post (ADCC) in the first of the Lincoln Laboratory buildings, and in the ADDC just completed at North Truro near Cape Cod. The transitional command posts led to the XD (experimental digital) -1 building of the Lincoln Laboratory, the prototypical SAGE center of 1954 (see Volume I, Part IV, and, Volume II, Chapter 5). Less well known is the parallel lineage of air defense command post test centers at and near Griffiss during 1949 into the 1950s.

As of 1949—two full years before the beginnings of similar efforts at Hanscom—the Data Utilization Laboratory set up Building 119 at Griffiss as a central locus for high-speed data simulators and computers, to tackle the electronics information issues of an air defense network (see Plate 156). The mission was identical in its basics to that undertaken during 1954-1955 in the XD-1 building (Experimental SAGE) at Hanscom. Even more striking is the choice of Building 119 itself. While Building 119 dated to 1941-1942,[26] the structure was a very good match for an early Cold War proto-hardened command post mission. Designed by architect J. Gordon Turnbull of Cleveland, the standard Armament, Fire Control, Supply, and Repair Building was windowless, and featured masonry construction (most often, reinforced concrete). Other examples of the structure exist at the Oklahoma City depot at Tinker Air Force Base and at the Warner Robins depot at Robins Air Force Base in Georgia. During World War II, the Oklahoma City Air Depot used the structure for the repair of Norden bombsights, adapting it in 1955 as a radar sighting station. Later in the 1950s and 1960s, the Oklahoma AMA remodeled the interior of the Armament, Fire Control, Supply, and Repair Building further through the addition of a collimator for calibrating missiles and a clean room for the repair and overhaul of missile guidance and flight control systems (see Volume II, Chapter 13). J. Gordon Turnbull was also the architect selected by Air Materiel Command for the design of a prototypical underground pilot plant, in 1948, with consultation between the command, Turnbull, and German engineers (see Volume I, Part III). The Data Utilization Laboratory planned to configure the Armament, Fire Control, Supply, and Repair Building with successive simulators and computers between 1949 and 1955 (Plate 157). Simultaneous with the adaptation of Building 119 for experimental studies applicable to air defense command posts, General Electric also set up a Test Operations Building for Air Materiel Command at company facilities in Syracuse. General Electric's Electronics Park of 1945-1947, designed by Giffels & Rossetti of Detroit, was an explicit model for the Cambridge Research Center under construction at Hanscom, and its Test Operations Building both predated and paralleled the Experimental SAGE building at the Lincoln Laboratory[27] (see Volume I, Part III).

Dr. Nicholson proposed sequential progress in data handling for air defense command posts and air traffic control centers. His work for the Cambridge Field Station complemented that of MIT professors and, as of 1951, the Lincoln Laboratory at Hanscom. During 1946 and 1947, he had noted

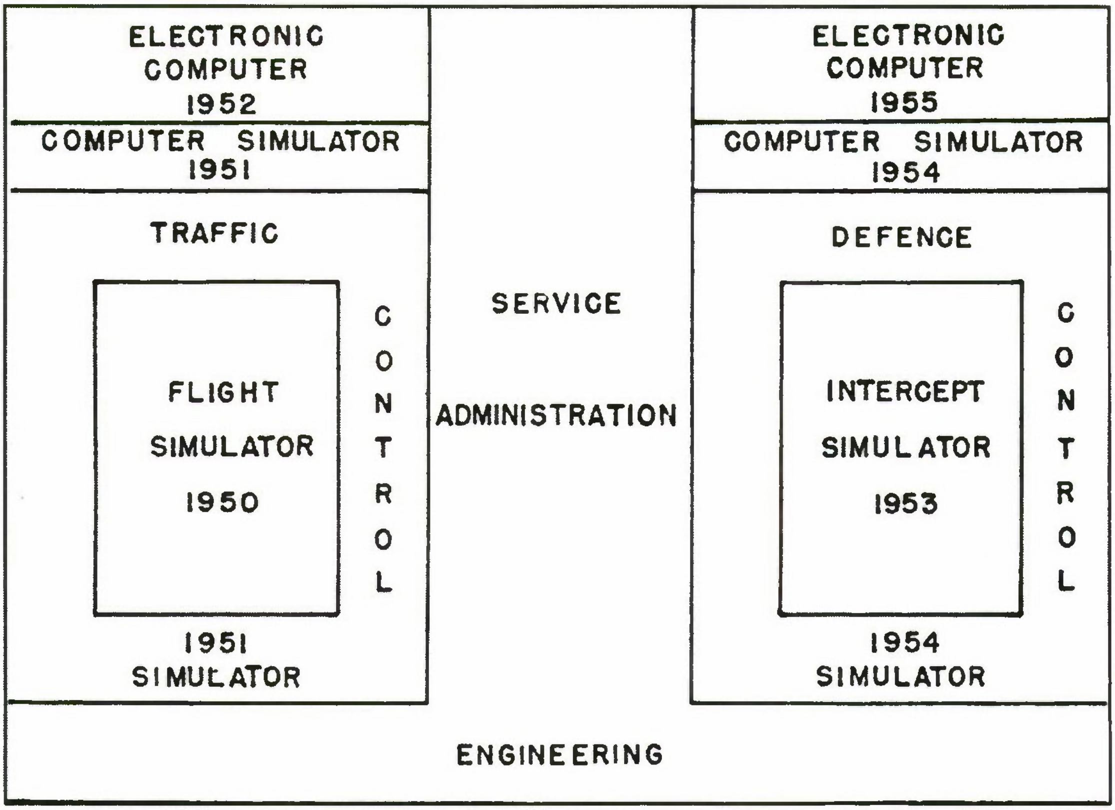

Plate 157: Interior layout of Building 119, the RADC, Griffiss Air Force Base, 1950-1955. In *Historical Data Air Force Cambridge Research Laboratories 3160th Electronics Group 1 July –31 December 1949.*

that his personnel had used both static and dynamic pictorial simulation studies to prove that pictorial displays could neither operate nor monitor high-speed data systems. In 1948-1949, his laboratory employed static simulation to illustrate that symbolic displays could monitor the types of high-speed data transmissions needed in air traffic and air defense work, and could in a limited manner operate related systems until automatic high-speed data systems were available (such as those planned through SAGE). Planning ahead, Dr. Nicholson forecasted that a dynamic pictorial simulation study of an air traffic control system could solve problems of scheduling and flight, "with aircraft of variable speeds between airports of varying acceptance rates," and that a related study of a "high speed binary digital computer...could determine the minimum computation requirements for the solution of problems in air traffic control." The air traffic problem for military and civilian aircraft was new as of the jet age in the early 1950s. As summarized in *Aviation Week*, the Air Force delegated the challenge to ARDC, who assigned it to the RADC at Griffiss.

> How do you schedule the orderly approach of dozens of jet aircraft, returning to their bases with near-empty fuel tanks, so that each plane arrives in position for its final approach at the proper time? If you can save five minutes of low-altitude delay in landing, you give a jet fighter another 10-15 minutes in combat. Or if you can double the number of bombers which can be landed at one airfield in a given interval, you eliminate the expense and trouble of building additional runways and / or airdomes.[28]

Dr. Nicholson anticipated that by 1953, "a dynamic pictorial simulation study...[could]...solve problems of scheduling and guidance of defense missiles intercepting offensive missiles attacking in various patterns and at various rates." Dr. Nicholson laid out a timeline for studies, as well as an evolved system applicable to air traffic control and air defense into 1960. His work exactly paralleled what MIT's Lincoln Laboratory would attempt in SAGE.

<u>1954</u>	Complete a dynamic pictorial study of a high speed binary digital computer to determine the minimum computation requirements for the solution of problems of air defense.
<u>1955</u>	Complete the construction of a high speed binary digital computer to solve problems in air interception with a minimum of computations.
<u>1956-60</u>	Combine the problem of simulation studies made on Air Traffic Control and Air Interception Control to permit simultaneous operation of the two control systems with a minimum amount of duplication of equipment and personnel.[29]

Dr. Nicholson's important presentation to administrators still in Boston at the Cambridge Field Station opened the door for two Air Force research programs for automated air defense command posts. The Cambridge Research Laboratories managed one effort, contracted to MIT's Lincoln Laboratory (Project Lincoln), while the nascent RADC at Griffiss initiated another under the guidance of Dr. Nicholson. During 1955-1953, a competitive scenario unfolded, with the University of Michigan filling the role of MIT for a contracted project monitored from Griffiss.

Efforts of 1949-1950 at Griffiss represented the leading edge of air defense research. The Data Utilization Laboratory advocated combining the ADCC and an Air Traffic Control Center for each region, with surveillance radar covering three airports and two ADC interceptor bases. Dr. Nicholson argued that what was developing as an overlapping system of civilian and military control centers become unified through combined command posts. His report of late 1949 to the Cambridge Field Station also focused on using high-speed digital computers to assess information and calculate launchings for air defense missiles. The computers would evolve as the AN/FSQ-7 and AN/FSQ-8 of International Business Machines [IBM], while the air defense weapons system matured as the Bomarc [<u>Bo</u>eing <u>M</u>ichigan <u>A</u>eronautical <u>R</u>esearch <u>C</u>enter] interceptor missile. For two days in early July 1950, the Watson Laboratories—anticipating a move to Rome, but still without Congressional approval for the relocation—hosted a conference at Griffiss reviewing the laboratories' development of electronics equipment and systems for air defense. The goal, simply stated, was improved visual displays and automatic transmission of evaluated radar information, to

> develop a complete system for plotting movements of radar targets for use in an operations room of a command radar set. The output of this system is to be a filtered display, indicating position and track of targets, together with other pertinent information related to these targets.[30]

As was also true for work at the Cambridge Research Laboratories the next year, first improvements in plotting boards were to be manual (see Volume II, Chapter 5). The Watson Laboratories summarized developments for several prominent projects. One dealt directly with plan position indicator (PPI) images on display boards. Optical enlargement, projection after conversion to a television scan, and projection after rapid photographic conversion were the three directions of

current research. The Data Utilization Laboratory at Griffiss planned to demonstrate new equipment before the close of the month.[31] The project evolved into Project Quick Fix at the North Truro ADDC near Boston in 1951 (see Volume II, Chapter 5).

Another aspect of the information display problem for air defense was the "human operator-equipment link." The human engineering project studied actual operations at ADDCs and ADCCs, including "statistical and time and motion studies leading to the [re]design and [re]arrangement of components [of the interiors of the centers]. Efficiency and simplification were the goals. The Data Utilization Laboratory would also study "problems in lighting, acoustics, form factor, selection and placement of controls and indicators and similar factors affecting human efficiency and fatigue."[32] The Watson Laboratories summarized work toward what it titled the Semi-Automatic Ground Control Intercept (SAGCI) computer. The contractor was to deliver the SAGCI computer to Watson Laboratories before the end of the summer, at the same time building identical equipment for the Navy. Conference presentations commented that negotiations were underway to have a SAGCI computer delivered to MIT in November 1950 for simulated tests and performance studies. MIT previously had a high-speed digital computer in development and test for the Office of Naval Research to analyze aircraft stability, resulting in the Whirlwind in 1947, and had shifted to R&D for the Air Force during the late 1940s (see Volume I, Part IV and Volume II, Chapter 5). Work toward a high-speed computer adaptable for tracking single aircraft interceptions (with a stated goal of late 1950), and then multiple interceptions (with a stated goal of 1953) was intense in 1950, with the SAGCI computer without doubt the Whirlwind I. MIT's Whirlwind I would evolve into the Whirlwind II and the AN/FSQ-7 and AN/FSQ-8 manufactured for SAGE by IBM. Although several oral traditions exist for the origins of the name SAGE, the acronym's earliest progenitor appears to be the RADC's referral to the Whirlwind as the SAGCI computer.[33]

In September 1950, Congress approved moving the Watson Laboratories from Red Bank, New Jersey, to Griffiss. Air Materiel Command completed the transfer of its Watson personnel in mid-February 1951, with 400 people relocating to Rome. With the formalization of the RADC in June, ARDC (the follow-on for the research half of Air Materiel Command) configured its electronics operations at Griffiss with about 800 civilian and 100 military personnel.[34] The Watson Laboratories also shipped its technical electronics library to Rome. The librarian transferred just after mid-year. As was also the case for the Cambridge Research Center, the RADC reviewed the organizational structure of other post-World War II military and industrial laboratories, seeking a viable model for contemporary electronics R&D. The RADC studied the Signal Corps (from whence it originated), Naval research laboratories, and the laboratories of General Electric, Radio Corporation of America (RCA), and Bell Telephone.[35] Adaptation of existing World War II buildings for the electronics mission at the base continued, with the conversion of Buildings 106 (an engine repair building) and Building 112 (an engine test building) into laboratories. Flight testing coordinated with ground radio and radar equipment was underway, and included not just tests involving facilities at the installation but also those at regional and distant contractor sites. In early June 1951, Dr. Nicholson left his position as the chief of the Data Utilization Laboratory at Griffiss. He returned to the Cambridge Research Center in Boston. Active projects of the Data Utilization Laboratory also moved back to the Cambridge Research Center, or closed out—although the laboratory continued to exist at Griffiss reconfigured for new missions. (Thus, Dr. Nicholson was at Cambridge for Project Quick Fix, and for the continuation of automated display research coordinated with the Lincoln Laboratory of MIT.) At Griffiss, efforts focused on the comprehensive display and manipulation of air defense radar data lay ahead. In late May, ARDC activated the Human Factors Branch (Office) on base, absorbing the human engineering mission proposed at the Watson Laboratories conference the previous summer.[36]

In 1951-1952, after more than six years of debate, the electronics R&D mission of ARDC (formerly, Air Materiel Command) began to settle out between the Cambridge Research Center and the RADC.

After mid-1951, the Data Utilization Laboratory of the RADC, under Major Richard M. Cosel, moved forward with work on data systems display for missile interception for what was unfolding as "project 'Bomarc' of the Air Force" and a British project "Peevish." For the Bomarc project, development of a Target Position Indicator was a top priority. Also critical was "the responsibility of directing the research and development of Operations Rooms and Centers." In July, the Data Utilization Laboratory erected a 100- by 40-foot prefabricated steel rigid-frame "Butler hangar" at Griffiss to house an Experimental Operations Room to improve existing war rooms within the network of ADCCs and ADDCs under construction across the continental United States since late 1949.[37] The "post-Nicholson" focus of the Data Utilization Laboratory was on the type of equipment used in the war rooms and its human management (Plate 158). Of note, the Experimental Operations Room at Griffiss did encapsulate Dr. Nicholson's earlier idea of a combined air traffic control center and an ADCC / ADDC. Major Cosel honed Nicholson's air traffic control idea further for military tactical control situations required in a battlefield or theater of war.

As early as September 1948, Watson Laboratories had held a meeting with TAC at Langley Air Force Base, the command's headquarters in Virginia, to discuss data transmission for a Tactical Air Control System. As presented by Dr. Nicholson's group, the system featured a Tactical Air Control Center (TACC) and a Tactical Air Direction Center (TADC), a network precisely paralleling ADC's ADCC and ADDC. The TACC / TADC system relied on forward area mobile radar information (in the

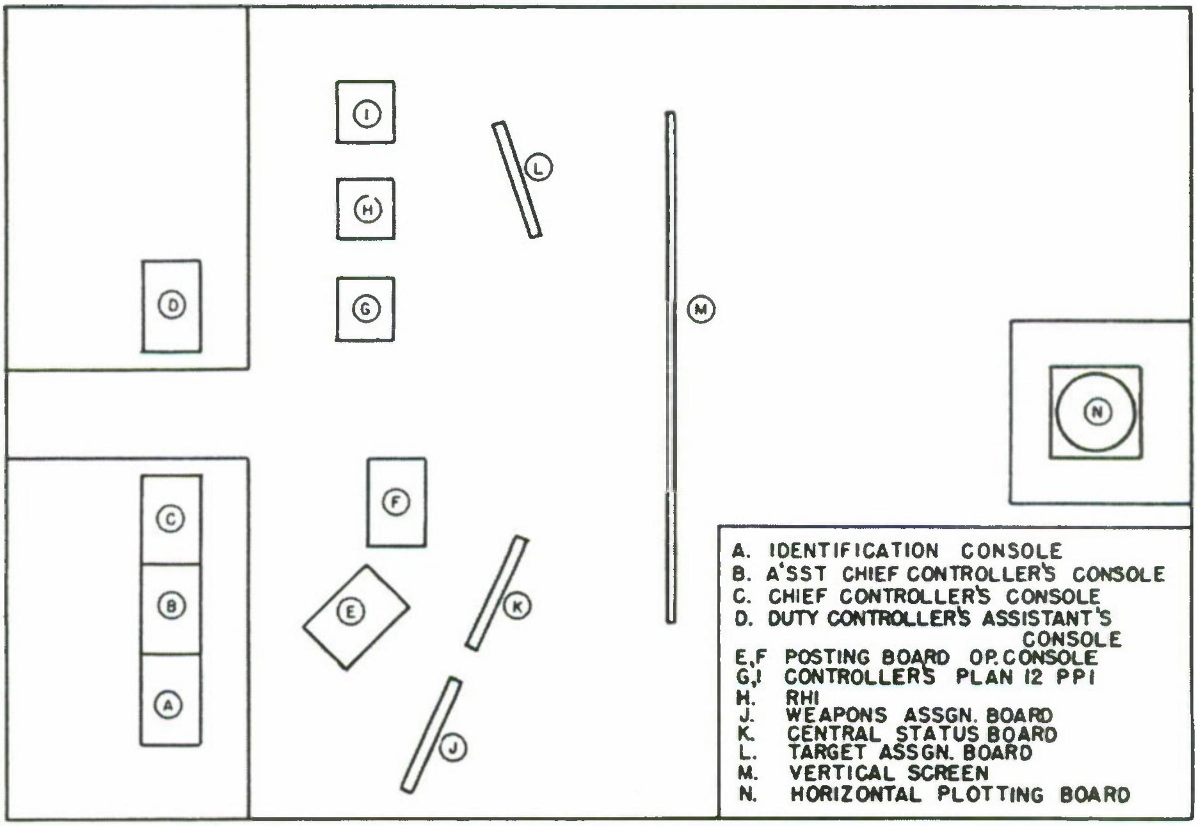

Plate 158: Interior layout in the Experimental Operations Room, the RADC, Griffiss Air Force Base, 1951-1952. In *Historical Data Rome Air Development Center 1 July – 31 December 1952*, volume 2.

TADC) processed in centralized automatic computers (in the TACC). The TACC further reported up to a Joint Operations Center (JOC) coordinating ground, air, and sea military operations.[38] TAC's air defense problem set closely resembled ADC's, and as such was a follow-on to the research toward a continental air defense network undertaken through Air Materiel Command and ADC beginning in 1946.[39] At Griffiss during 1951-1952, the Data Utilization Laboratory tested ADCCs / TACCs and ADDCs / TADCs under "actual operational conditions,"[40] setting up an experimental facility on base with an AN/CPS-5 radar at what was designated Site 10 (see Plate 163). (Family housing of late 1957 subsequently replaced Site 10, located east of the installation hospital.[41]) The timing of the Site 10 facility coincided with the Korean War and testing of TAC's TACC / TADC network was uppermost, although the Air Defense Laboratory (MIT's Lincoln Laboratory at Hanscom) and the Research and Applied Techniques Laboratory (at Griffiss) were "all involved in this particular project." In 1953, ARDC anticipated that the site would become a microwave relay terminal. Intent was to test the Target Position Indicator, "semi-automatic posting status boards, and an improved tactical display." Simultaneously, the Human Factors Office studied ways to better design needed electronic equipment.

During 1951-1954, the RADC at Griffiss took shape primarily as a composite of modified World War II buildings, with a laboratory and an electronics warehouse erected as new construction. Late in 1951, the RADC converted Building 112, the early 1940s engine test facility, for use as climatic chambers.[42] Building 112 was of reinforced concrete construction, designed as a standard structure by J. Gordon Turnbull and featuring individual test cells for run-ups of aircraft engines[43] (see Volume II, Chapters 6, 11, and 13 and Volume II, Plate 75). The ingenious conversion of the eight cells at Griffiss to climatic chambers allowed the RADC to drive in mobile radar or avionics trailer units, closing individual cells and running temperatures down as low as -70 degrees Fahrenheit (F) or up as high as 190 degrees F (see Plate 156). Personnel could also humidify the environment within a range of 10 to 95 percent (Plate 159). The RADC remodeled four of the 16- by 13- by 17-foot cells as Arctic test chambers and four as tropic chambers. The Arctic cells had a temperature range of -70 degrees F to 72 degrees F, the tropic cells, 34 degrees F to 190 degrees F. One Arctic chamber could also simulate altitudes up to 70,000 feet, while one tropic chamber could create rain (100 percent humidity).[44] At the close of 1951, continuing into 1952, the RADC began converting Building 106, the engine repair facility for the Rome Air Depot of 1941, to radar and navigation

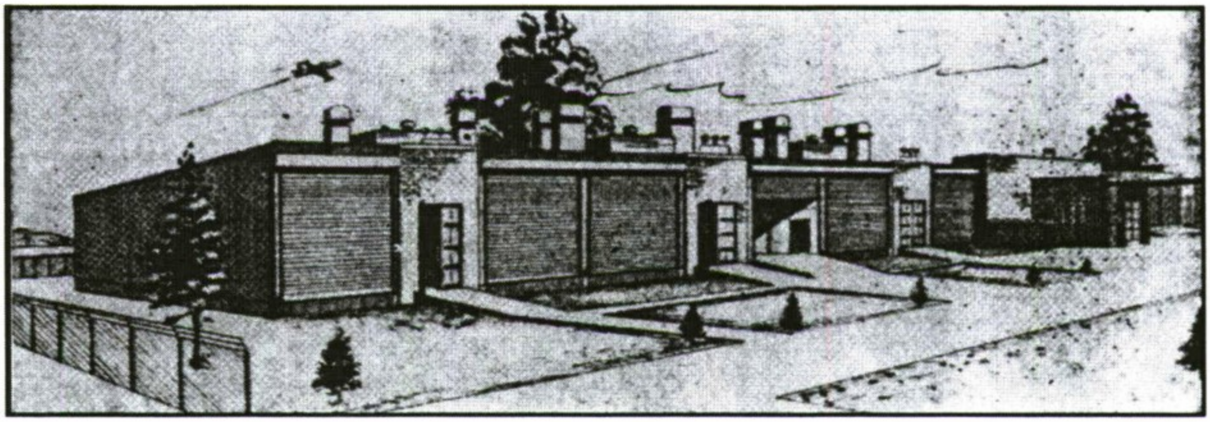

Plate 159: J. Gordon Turnbull. Engine Test Cells (Building 112), Griffiss Air Force Base. Adapted as Arctic and Tropic Climatic Test Chambers for the RADC, 1951-1952. In *Aviation Week*, 17 August 1953.

laboratories, adding a wing to the structure[45] (Plate 160). In October 1952, the Army Corps of Engineers, New York District, hired Alexander D. Crosett & Associates to use a set of drawings executed by Cram & Ferguson of Boston to complete an air defense (intelligence and aerial reconnaissance) electronics laboratory at Griffiss.[46] Building 240 was directly derived from Building C of MIT's Lincoln Laboratory at Hanscom (Plate 161). Cram & Ferguson's design of Building C (Building 1302C at Hanscom) dated to late December 1951, under construction nearly simultaneously at both Hanscom and Griffiss. ARDC erected "Building C" as a part of a multibuilding air defense laboratory complex at the Boston installation, but as a single laboratory wing in Rome (see Volume I, Part III and Volume II, Chapter 5).

Also in October 1952, Alexander D. Crosett received a set of drawings from the Corps of Engineers for a 160,000-square foot warehouse.[47] The original design dated to April 1952 and was that of L.P. Kooken, of Baltimore, for the Special AMC [Air Materiel Command] Warehouse. Air Materiel Command erected the warehouse at its depots in 20 locations. The command built the Special AMC Warehouse both for major AMAs and at selected special depots, in single, double, and triple configurations during 1952-1958. Adaptation for Griffiss coincided with Air Materiel Command's reinstatement of a logistics function at the base in late 1951, through the designation of a depot for ground communication and electronics equipment subsumed under the Middletown AMA at Olmsted Air Force Base in Pennsylvania. The Special AMC Warehouse was a highly significant project for Air Materiel Command, featuring a rigid-frame reinforced concrete modular system and precast concrete panels for the walls and roof in its most advanced variation. The international engineering community discussed the experimental warehouse widely, publishing articles about the structure in multiple professional journals during the 1950s. The warehouse built at Griffiss (Building 3) was the very first Special AMC Warehouse erected nationwide (Plate 162), although what appears to have been a prototype for the structure went up in 1951 at Tinker in Oklahoma City (see Volume II, Chapter 13). Several of the Special AMC Warehouses built before 1955 suffered dramatic partial roof failures and cracking of their concrete rigid-frame system. The situation caused Headquarters Air Materiel Command to hire Ammann & Whitney, a prominent New York engineering firm known for its abilities in structural analysis, to review damaged warehouses at selected depots. Ammann & Whitney created a retroactive solution, strengthening the warehouse through external steel strapping where already built (true at Griffiss, Robins and Tinker, and for two of the warehouses erected for the San Antonio AMA at Kelly Air Force Base). Ammann & Whitney revised the basic design where construction was in progress or where the warehouse was still to be erected (as at McClellan and Hill Air Force Bases in California and Utah, respectively) (see Volume II, Chapters 6, 7, 10, 11, and 13). The Ammann & Whitney retrofit for the warehouse at Griffiss dated to May 1957, after a survey of structural cracking made in April.[48] Griffiss fully ceased its depot function for AFLC in early 1967, following several years of decisions in this direction. AFSC adapted the warehouse in its later life for electronics testing, remodeling the interior to include several anechoic chambers.[49] The RADC dedicated Building 3 as an electronics laboratory in October 1968, after construction of an addition.[50]

While construction for the RADC was going forward at Griffiss during 1952-1953, the center contracted with the Aeronautical Research Center of the University of Michigan at Willow Run (Ypsilanti) for an air defense study paralleling that of MIT on Project Lincoln. In early April 1952, ARDC held a second air defense conference at Griffiss (the first had occurred in July 1950). Representatives of Headquarters Air Force, Headquarters ARDC, the Cambridge Research Center, MIT (Project Lincoln), the Air Force Missile Development Center (at Holloman Air Force Base in New Mexico), the National Research Laboratories, and the Bureau of Ships attended. (The latter agency was at the meeting to discuss R&D for planned radar picket ships.)[51] Both the RADC and the Cambridge Research Center, and their contracted universities, approached the challenge of an automated air defense command post network similarly, but with distinct details. The study

Plate 160: Radar and Navigation Laboratories (Building 106), the RADC, Griffiss Air Force Base. Conversion of an early 1940s engine repair shop. Undated photograph. Courtesy of the History Office, Rome Research Site, AFRL.

Plate 161: Cram & Ferguson. Intelligence and Reconnaissance Laboratory (Building 240), the RADC, Griffiss Air Force Base, 29 October 1953. In *Historical Data Rome Air Development Center 1 July – 31 December 1953*, volume 2.

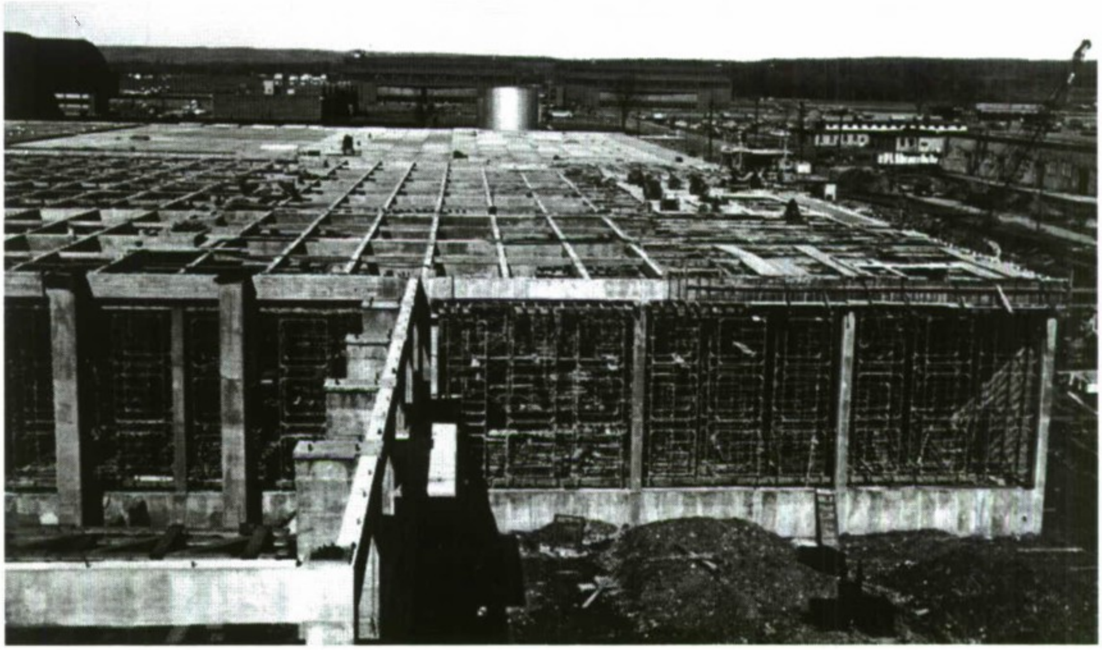

Plate 162: L.P. Kooken and Ammann & Whitney. Special AMC Warehouse, Griffiss Air Force Base, 29 October 1953. In *Historical Data Rome Air Development Center 1 July – 31 December 1953*, volume 2.

channeled through the RADC was more closely tied to Bomarc and the refinement of the data display systems internal to war rooms, while the study through Cambridge emphasized the capabilities of MIT's Whirlwind computer. The RADC contracted with Willow Run, negotiating task orders. The Human Factors Office of the RADC (formerly, Human Engineering) also contracted with multiple universities for studies applicable to the varied aspects of the configuration and operation of air defense war rooms. One example was a contract to the College of Arts and Sciences at the University of Rochester to evaluate color perception related to electronic information displays in command posts.[52]

Both Rome and Cambridge looked at relative numbers and hierarchy for automated command posts, with differing recommendations. The University of Michigan adapted the Comprehensive Display System (CDS) of the British Navy to American radar technology for air defense, renaming their version of the system as the Air Defense Integrated System (ADIS). By at least 1952, British and Canadian officers were in place at Griffiss, explicitly to foster "a closer cooperation, understanding and exchange of information...between the United States and some allied nations in respect to electronic research and development." In August the same year, the RADC also sent representatives to England to study the R&D progress of British radar.[53] The Willow Run location for the joint RADC - University of Michigan study, southwest of Detroit, was also the site for an ADCC just reaching completion in 1952. The collocation of the Willow Run ADCC with the University of Michigan Aeronautical Research Center paralleled the proximity of an ADDC at North Truro, Massachusetts, for coordinated experimentation run through the Cambridge Research Center and MIT for Project Lincoln (see Volume II, Chapter 5). ADC erected another ADCC near Griffiss at Hancock Field in Syracuse, although its use for studies underway at the RADC is undetermined. The ADCC at Hancock Field was an off-site tenant responsibility of Griffiss (see Volume I, Part IV).

By mid-1953, the RADC additionally sponsored 11 active on-base sites for electronics testing at 15 numbered locations, with several of these ancillary facilities additionally contributing to the air traffic control and operations functions of the installation.[54] Identified and mapped in early 1957 (Plate 163), these on-base test locations were generally ephemeral, but in selected instances were of high importance. By 1957, Site 7 was no longer mapped and the RADC had designated two more test locations on base. Most sites supported the testing of radar equipment.[55] Sites 1A and 1B, located at the west end of the east-west runway, featured radar for ground control approach, taxi control approach, taxi control and automatic ground control approach, and traffic control (for the latter, including erection of an AN/CPN-18 and an AN/TPS-16).[56] Site 2 supported three 30-foot, and two 50-foot, masts for making pattern and other measurements in antenna tests. Site 3 served as an alternate for Site 1A, at the eastern end of the east-west runway. Site 4 is of unknown original use and was turned over to the Airways and Air Communications Service by early 1953. Site 5 tested the AN/CPS-8 taxi control radar and functioned as a high-precision radar test location (and included a theodolite). Site 6, at the western edge of the base, featured an AN/MPN-7 used in conjunction with radar reflectors to test the accuracy of radar equipment range calibration.[57] Site 7 initially hosted an experimental control tower, although the Air Force earmarked both Sites 4 and 7 for reuse on later projects. Site 8 at the northern edge of Griffiss tested experimental direction finding equipment, including a CRD-6 and an MX (missile experiment) -536/GRD. The CRD-6 was an ultrahigh frequency [UHF] direction finder.[58] The MX-536 project was one for the remote-control flying of the Bell Aircraft YP (prototype pursuit) -59A,[59] the first experimental jet fighter (see Volume II, Chapters 3 and 15). Located southeast of the World War II POW area, Site 9 was the radio station for point-to-point and air-to-ground communications needed in flight tests. Site 9A occupied the POW area itself, used by the RADC for applied propagation and antenna studies. (The specific nature of the POW camp is as yet undetermined—German, Italian, or Japanese. The region around Rome, New York, was heavily settled by immigrant Italians.) Site 9A included a 40-foot platform and mast, as well as a second 110-foot mast.

Three of the remaining sites featured more complex testing tied to much larger efforts. Site 10 featured the Experimental Operations Room and an AN/CPS-5 radar, by 1953 noted as part of the "semi-automatic Ground Control Intercept System" (again, a name moving quickly toward SAGE). Site 11 sat on Picnic Hill northeast of the northeast-southwest runway. The RADC employed it for evaluating close-support radar such as the AN/MSQ-1.[60] Site 12 occupied a location near the center of the same runway and featured a piece of rotating equipment for an AN/FPN-16 radar[61] to monitor ground-controlled approach (GCA). Contemporary GCA procedures were dependent on prevailing winds, with equipment mounted in mobile trailers that were moved and realigned under changed conditions—a time consuming and cumbersome process. The rotating AN/FPN-16, with its unusual base, was a high-dollar experiment for the RADC, costing about $170,000 and illustrated in *Aviation Week's* issue on ARDC of August 1953. The turntable included a set of tracking computers and could rotate 360 degrees in three minutes, "at the push of an appropriate button." Craig Machine, Inc., of Danvers, Massachusetts, built the device. The RADC installed the prototype at Griffiss for test and evaluation. The Air Force planned to set up the AN/FPN-16 across its installations beginning in late 1953. The Watson Laboratories in New Jersey had constructed the very first version of the device just after World War II. The turntable-mounted GCA station, also referenced as an Automatic GCA (AGCA), allowed a single GCA unit to cover instrument approaches from more than one direction, on more than one runway. The AGCA could handle six aircraft on final approach simultaneously (Plate 164).[62]

At Site 13, the RADC evaluated the CW-209 / CPS-6B radome under cold-weather conditions.[63] ADC and TAC needed radomes to protect their radar equipment at stations operating under severe Arctic conditions that included ice and wind. In mid-1950, Goodyear Aircraft Corporation in Akron, Ohio, had the contract to develop a light-weight, air-supported, dual-nylon wall radome for the

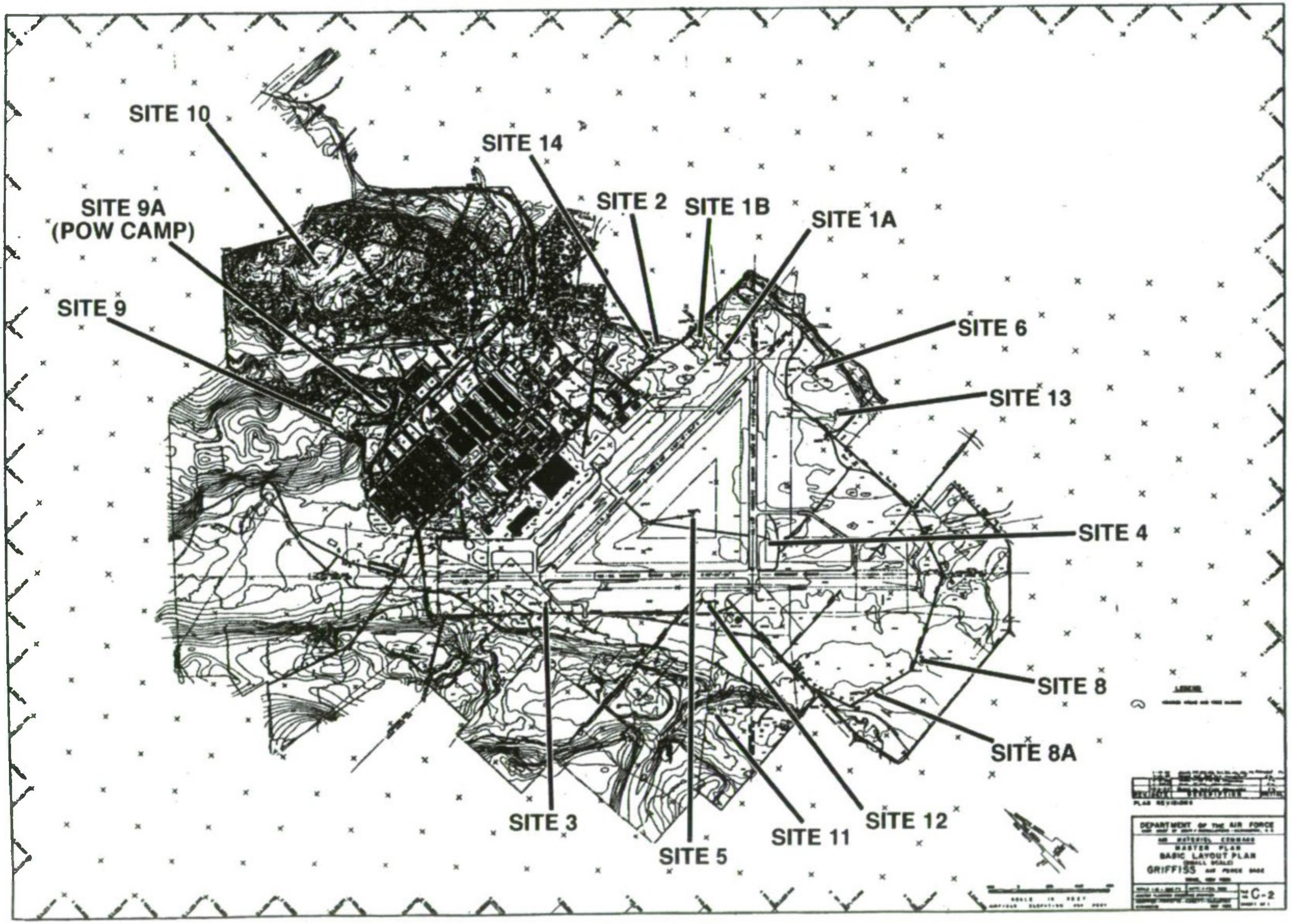

Plate 163: Sites 1-14, Basic Layout Plan, Griffiss Air Force Base, 4 February 1957. Site 7 is of unknown location. Site 9A was a POW camp during World War II; Site 10, the Experimental Operations Room. Site 14 is of unknown test use. Courtesy of the Environmental Planning Offices, Rome Research Site.

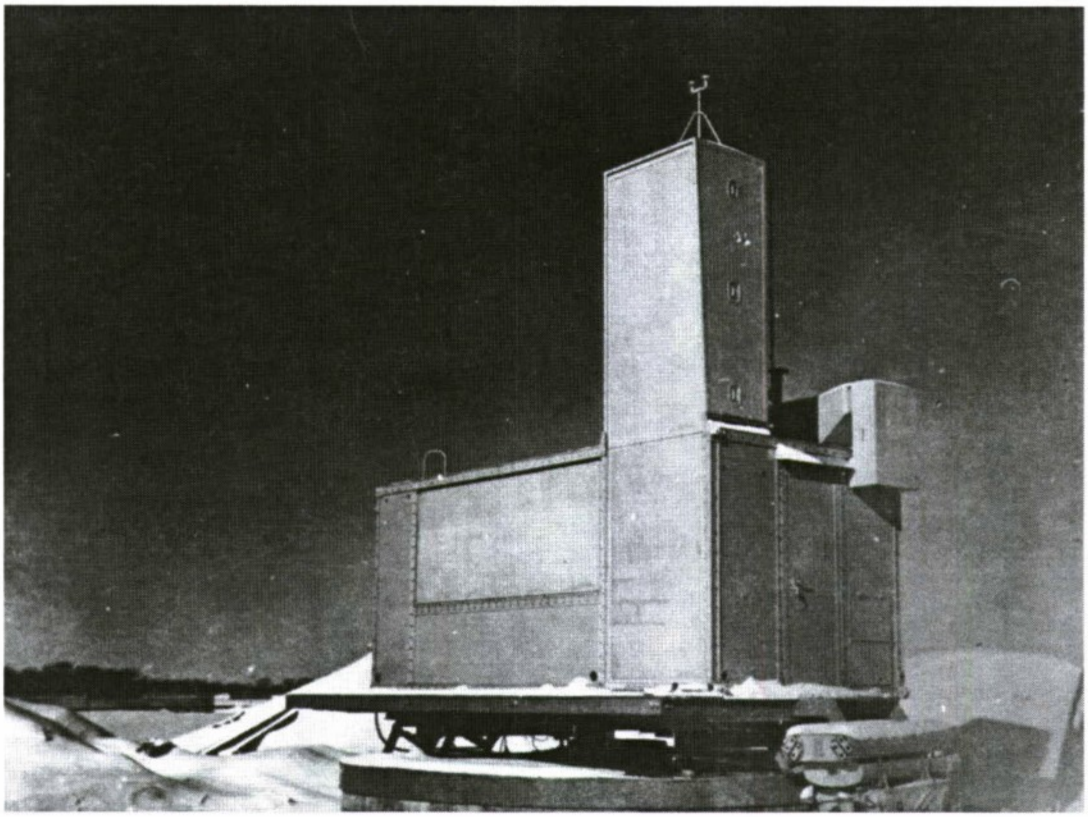

Plate 164: Craig Machine, Inc. Automatic Ground-Controlled Approach, Rotating Turntable with Mounted AN/FPS-16 and Tracking Computers, Site 12, Griffiss Air Force Base. In *Historical Data Rome Air Development Center 1 July – 31 December 1953*, volume 2.

AN/CPS-6B, shippable to location and easy to erect. The radome was also to be capable of withstanding a wind velocity up to 129 knots under a temperature range of –230 degrees F to 100 degrees F.[64] The Dresser Equipment Company (IDECO) of Columbus, Ohio, designed and fabricated the base structure for the radome.[65] IDECO was responsible for other contracts for experimental aluminum structures for Headquarters Air Materiel Command during this same period (see Volume I, Part IV and Volume II, Chapter 14). In February 1953, the RADC held a conference at Griffiss on radome R&D, with representatives of Air Materiel Command and private industry present. By this date, the choice of sheathing materials for radomes was under review. The RADC looked at fiber-thin materials made by the United States Rubber Company and neoprene coatings by DuPont for its radomes, and requested that Goodyear test a single-wall radome in addition to the dual-walled structure. Lincoln Industries was working on a rigid-frame radome in four variations, using panels of Dacron cloth, low dielectric fiberglass, regular fiberglass, and a paper honeycomb. The RADC tested sample radome panels atop Building 104 at Griffiss, as well as erecting a 50-foot production air-supported radome at Site 13.[66] The final test area, Site 14, was not present in mid-1953, but was mapped by 1957. Its historic test function is unknown.

The RADC began to establish radar and electronics test sites off base during the early 1950s. By mid-1953, eight Geographically Separate Units (GSUs) were in place. The number of GSUs increased to 17 by 1957 and fluctuated over the decades thereafter. Most of the annex sites were in the immediate vicinity of Griffiss,[67] although several test locations were thousands of miles distant

(Plate 165). The RADC GSUs were typically of small acreage. The first test site was the Forestport Test Annex, under construction in 1950. The 182-acre Forestport site hosted a very low frequency (VLF) transmitting station featuring a 1,218-foot radio tower for long-range navigation experimentation. When erected, the VLF tower was the second-tallest man-made structure in the world, taller than the Eiffel Tower in Paris (984 feet) and comparable to the Empire State Building in New York (1,250 feet). RADC built the Forestport VLF tower as one of three facilities to support initial testing for the long-range radio navigation (LORAN) system[68] (Plates 166-167). (The VLF tower is demolished today.) The second annex site, that of Verona in 1951, covered 325 acres and initially included a six-room concrete block building, with a small power station and radar platform.[69] In mid-1952, the RADC installed an AN/CPS-3, AN/CPS-4, and AN/CPS-5 at Verona, adding 12 buildings and more equipment by June 1953 (including an AN/FPS-6 radar).[70] Communications lines linked the Verona radars to facilities on Griffiss proper, as well as to facilities in Watertown and Syracuse, New York—suggesting radar air defense testing tied to the ADCC and ADDC command post network.[71] Over time, the RADC augmented the Verona Test Annex to nine laboratories with eight small individual power stations, and 17 radars. Five of the radars at Verona were Arctic in type with enclosed radomes, while 12 were open towers appropriate for a temperate climate[72] (Plate 168).

Construction at Verona was intense during the early 1950s and again at the end of the Cold War. Verona supported testing for electronic counter and counter-countermeasures (ECM / ECCM) equipment, electronic warfare simulators, radars, and communications equipment. The variety of radars tested at Verona enabled the RADC to simulate foreign equipment to determine its resistance to jamming and its electromagnetic vulnerability. The Verona Test Annex also supported the evaluation of airborne antennas and weapons systems, and had assigned flight test aircraft, as well as periodic missions that included the aircraft of ADC, TAC, SAC, the Navy, the Army (helicopters), and the British Royal Air Force (RAF). The Verona site was part of the RADC Experimental Tropo Range extending between Verona and Youngstown, New York, for real-world testing of troposcatter communications used in the components of the Distant Early Warning (DEW) Line in northern Canada and in the White Alice Communications System (WACS) of the early 1950s. In 1968, the RADC added a laser propagation test facility at Verona. The late Cold War work at the test site focused on space communications R&D for the Strategic Defense Initiative (SDI).[73]

The other early 1950s test annexes were those of Floyd and Newport, New York; an omnirange and short-range navigation test facility in the town of Rome (the Jervis Avenue site, two miles from the base); and, three far-distant GSUs—for long-range, low-frequency navigation testing in Adamston, New Jersey, and, test sites for navigation system studies in Carrabelle, Florida, and Cape Fear, North Carolina.[74] The Floyd Test Annex was in progress in 1952 (operational into the early 1980s). Floyd offered an experimental location for direction-finding and radio communications equipment in a static-free environment. The RADC used Floyd in some of the very first satellite communications tests, including one notable test in 1960 featuring radar signals bounced from Trinidad in the Caribbean, to Floyd (see Volume I, Part IV and Volume I, Plates 124-125). The Newport site, constructed in 1953, featured two discontiguous test facilities on Tanner (receiver site) and Irish (transmitter site) Hills. The two sites were a mile from one another, separated by a 400-foot wide valley. Newport offered a quiet electromagnetic environment within which the RADC could gather antenna pattern and coverage data on fighter aircraft. Initially, the Newport Test Annex functioned as a proving range for all types of radar antenna and operated under the control of the Electronic Warfare Laboratory of the RADC.[75] Beginning in 1971-1972, the Newport Test Annex included pedestals for mounting aircraft upside down to evaluate the effects of fuselage with externally mounted equipment such as fuel tanks, missiles, and other inert weapons on antenna patterns and radar signatures.[76] The Rome Research Site can test varied operational stores configurations in this manner, similar to scale-model tests done at the AEDC in Tennessee. Testing fighter aircraft atop pedestals substitutes for long hours of flight testing. It also permits testing from any position within a 360-degree range and at differing angles[77] (Plate 169).

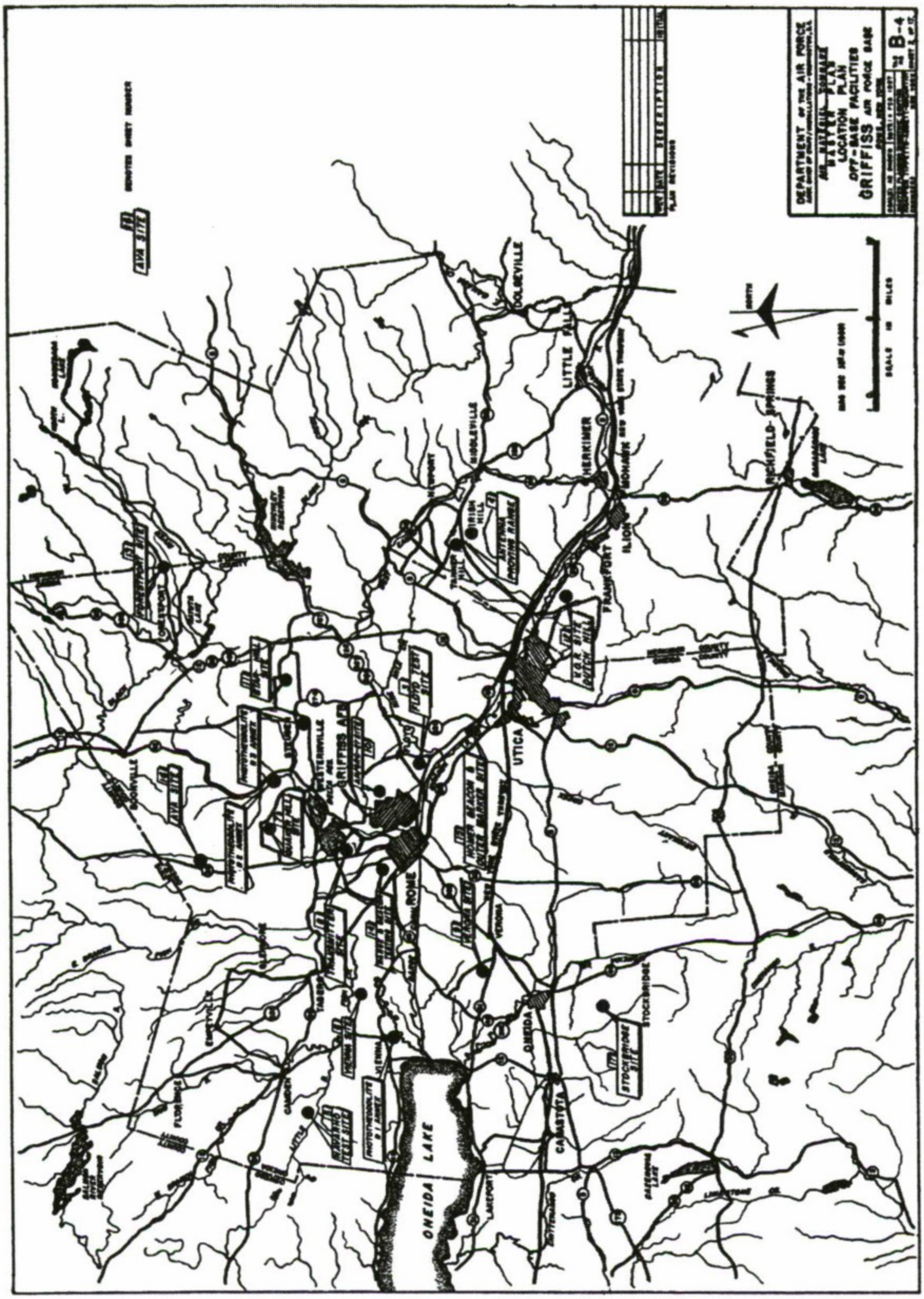

Plate 165: Geographically Separate Units (Annex Sites), the RADC, Griffiss Air Force Base, 4 February 1957. Courtesy of the Environmental Planning Offices, Rome Research Site.

Other off-site RADC GSUs in New York included those of Starr Hill (1954), Camden Hill (Camden 1; also known as the Navarho site) (1954), Quaker Hill (1955), Vienna (1956), North Osceola (also known as Dean Hill) (1956), Clark Hill (1957), Ava (1957), Stockbridge (1957), Ransonville (1958), Tummonds Hill (also known as the Ontario Test Annex) (1965), Youngstown (1965), West Lee (1969), and Eagle Hill (1965), as well as the V.O.R. (VHF Omnidirectional Range) site at Dutch Hill (by 1957), three phototheodolite annexes, a homing beacon location, and an AN/GRC-27 radar site.[78] Each of the test sites accommodated differing types of radar, electronics, and communications evaluations during the Cold War. Personnel at the RADC used:

- Starr Hill for high frequency propagation research (testing the guidance and control system for the Atlas intercontinental ballistic missile [ICBM]);
- Camden Hill for low frequency antenna analysis;
- Quaker Hill for testing calibration and position-finding equipment;
- Vienna and Eagle Hill for evaluating targeting measures;
- Tummonds Hill, Ransonville, and Youngstown for testing troposcatter communications links as termini for the 100-mile Experimental Tropo Range extending west from Verona (with Youngstown originally built as a Nike missile installation in 1954);
- Stockbridge
  - for testing high frequency (HF) antennas, with line-of-sight to Griffiss and the Ava, Camden, Forestport, and Verona GSUs,
  - for early research on Over-the-Horizon (OTH) radar as of 1970, and
  - for assessing large aircraft antenna systems as of the middle 1970s;
- Dean Hill for evaluating mobile acoustics (microphone and infrasonic array testing);
- Clark Hill for analyzing electronic intelligence;
- West Lee for evaluating intrusion detection techniques; and,
- Ava for experimentation with OTH radar complementing that at Stockbridge.[79]

In 1970, the RADC also established the Northeast Test Area Range at Stockbridge to conduct temperature zone evaluations for advanced surveillance technologies.[80] Parallel kinds of temperature-sensitive testing for surveillance equipment, as well as more generalized testing of radar, reconnaissance sensors, and electronic warfare devices, occurred on the ranges associated with Eglin in the Florida panhandle.[81]

Among the early test annexes, one of the more unusual was Camden Hill. The RADC initially planned the Camden Hill site to test Navarho, a long distance navigation system able to supply distance and azimuth data from a single site[82] (Plate 170). The Navarho system employed a technology called Navaglobe, a low-frequency 100-150 kilocycle omnirange system developed by Federal Telecommunications Laboratories, Inc. (also working on components of Navaglobe at the Adamston site in New Jersey). Navaglobe had an effective range of 1,500 nautical miles, with a bearing accuracy of one-half to one degree. Navaglobe was in test as an alternate to LORAN. The Camden Hill Test Annex for Navaglobe featured three antennas configured as an equilateral triangle 9,500 feet on a side, complemented by three transmitter buildings, three antenna tuning shelters, an operations building, towers and telephones. The RADC estimated systems cost for the Navaglobe as over $300,000 in 1953. Actual cost topped $600,000, with construction delayed until 1955-1956.[83] Intent was for a Navaglobe station to cover seven million square nautical miles, transmitting a synchronizing pulse simultaneously from all three antennas. Navaglobe featured a strong signal to noise ratio. Aircraft carrying a Navaglobe receiver could automatically establish its bearing relative to a transmitting station.[84] The RADC had accepted 10 Navaglobe units from Federal Telecommunications Laboratories, Inc., in 1952.[85]

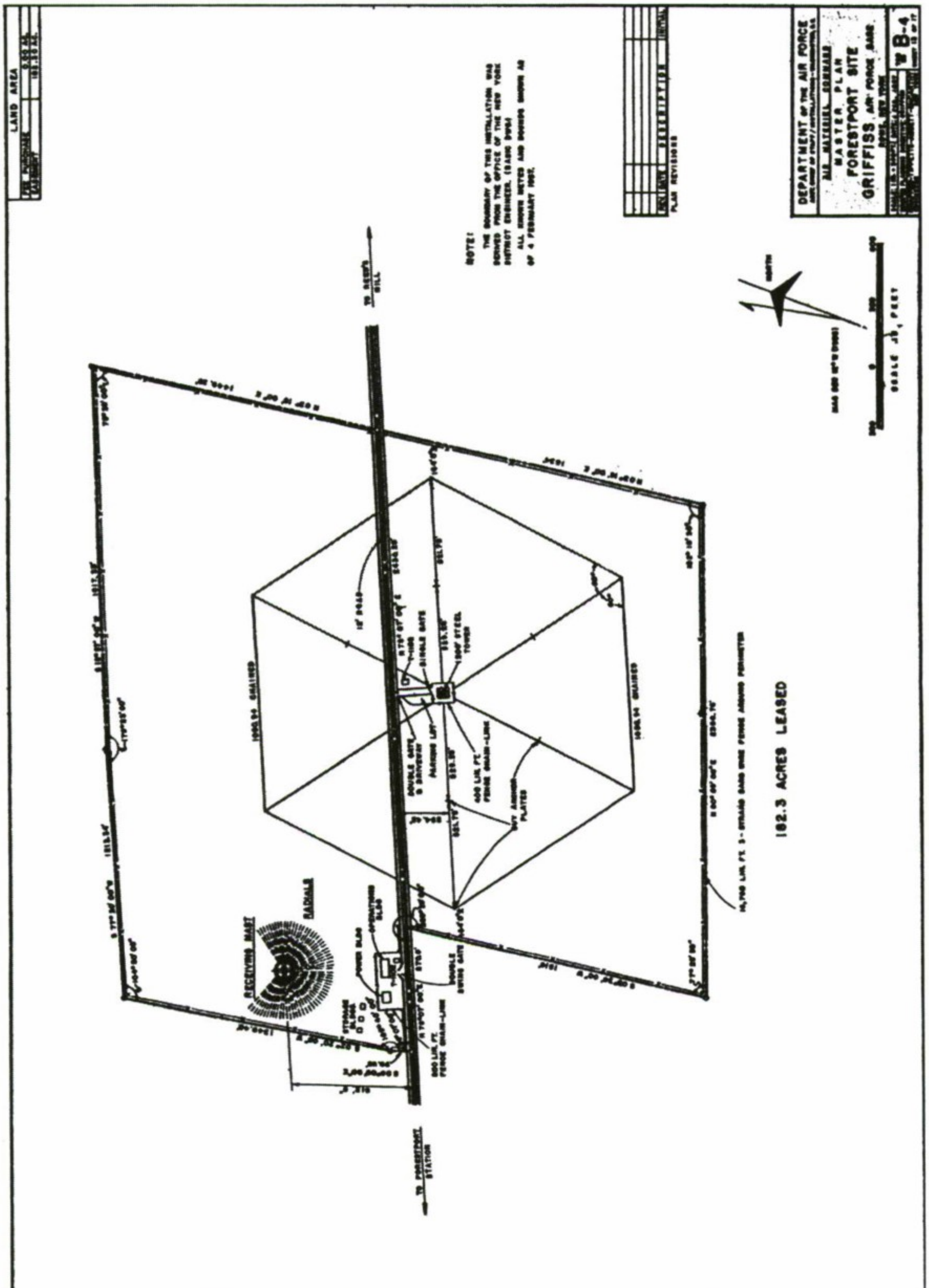

Plate 166: Forestport Site, Master Plan, 4 February 1957. Annex located six miles northeast of Forestport, New York. Courtesy of the Environmental Planning Offices, Rome Research Site.

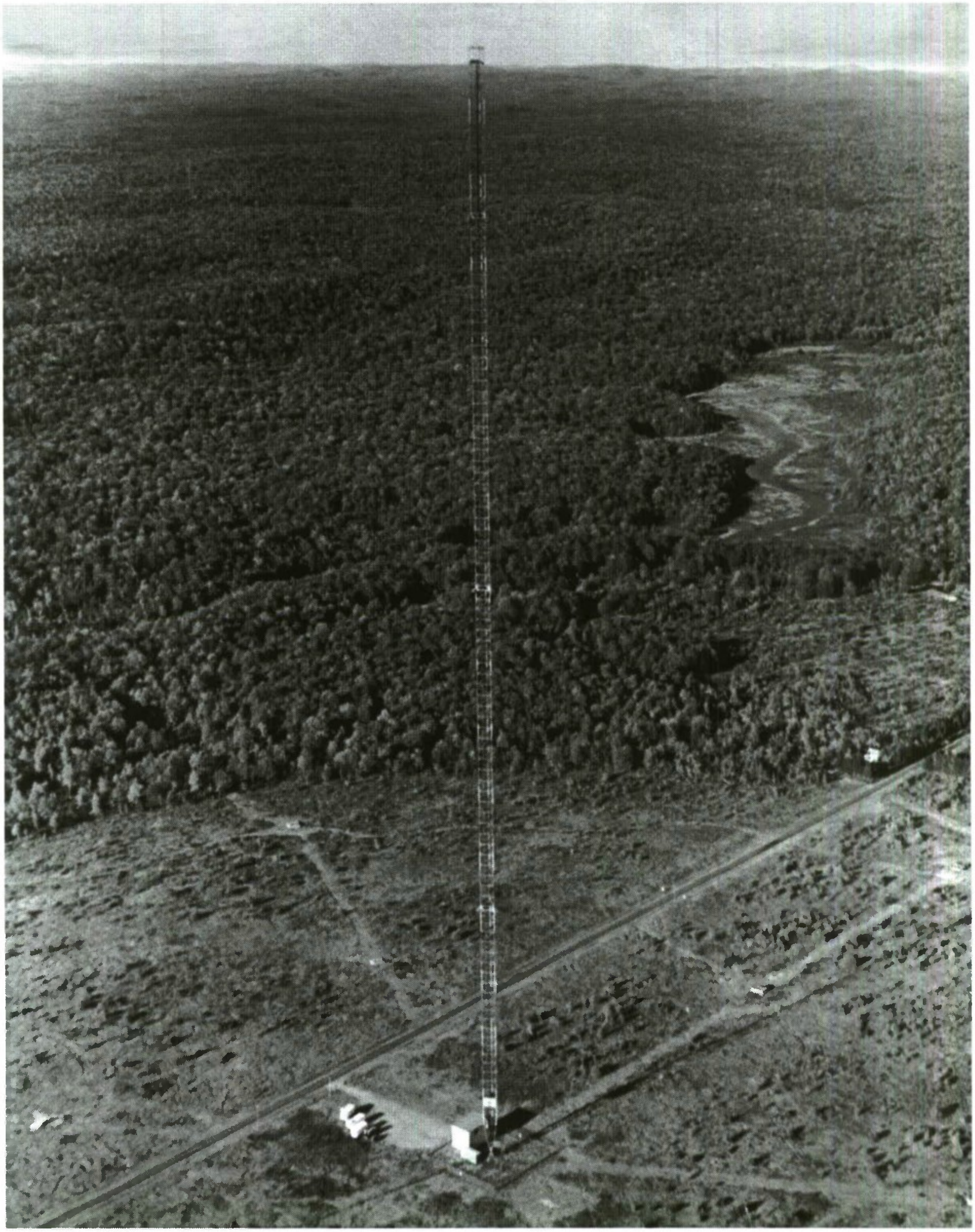

Plate 167: Very Low Frequency 1,200-Foot Radio Tower, Forestport Site. Undated photograph. Courtesy of the History Office, Rome Research Site, AFRL.

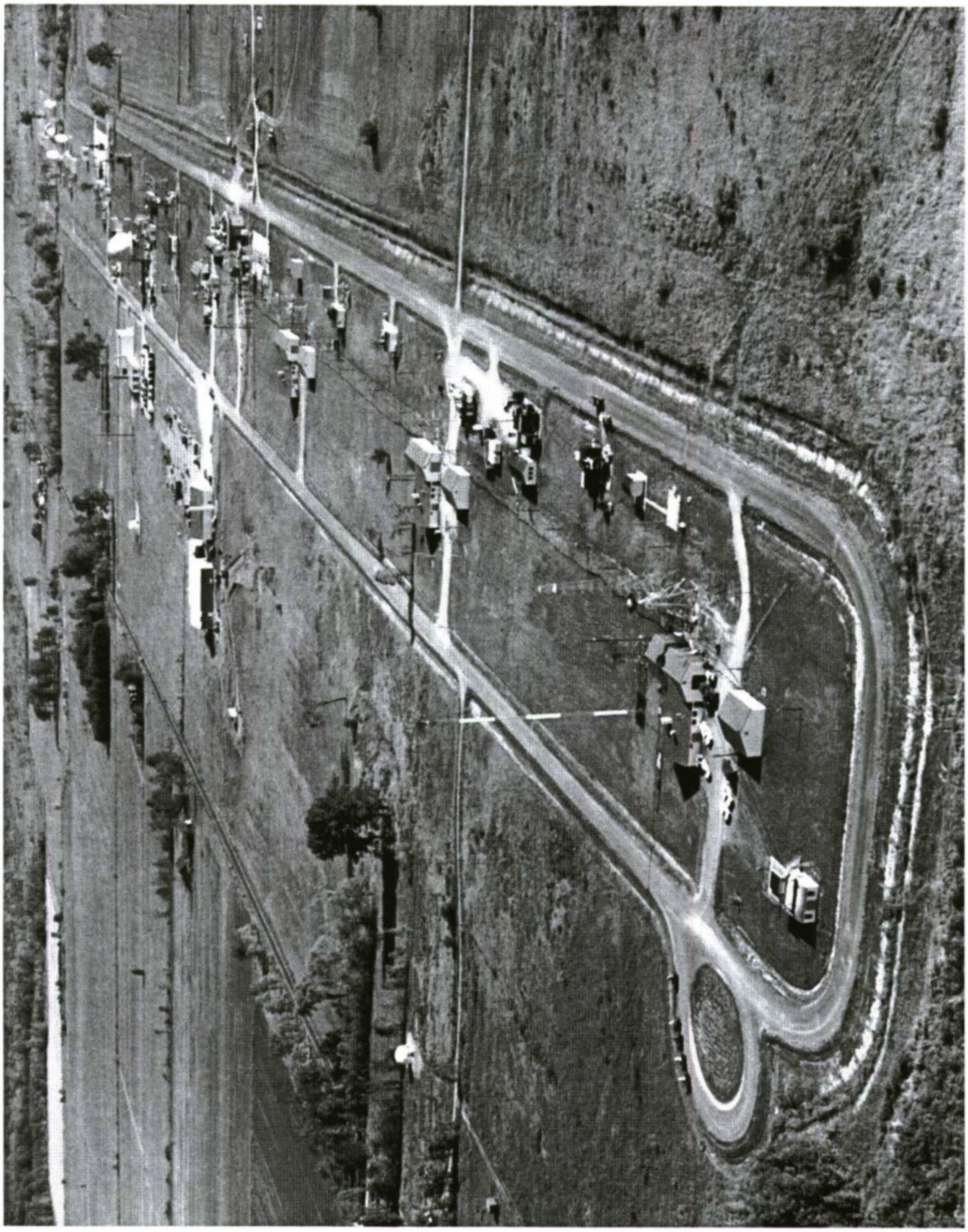

Plate 168: Verona Site, three miles northwest of Verona, New York. Undated photograph. Courtesy of the History Office, Rome Research Site, AFRL.

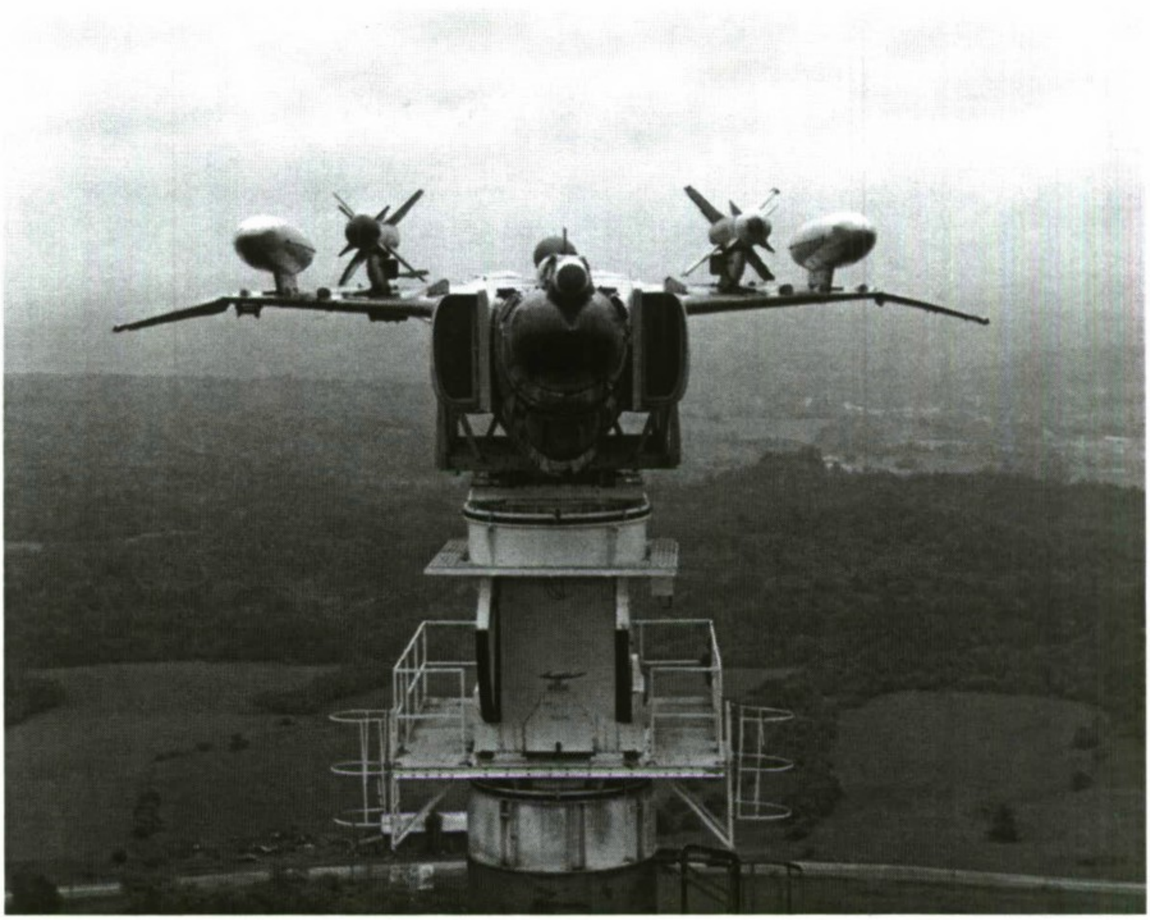

Plate 169: Newport Site, four miles southeast of Newport, New York. F-4 mounted upside down on a vertical pedestal for fuselage and stores pattern testing. Undated photograph. Courtesy of the History Office, Rome Research Site, AFRL.

Accomplishments through the RADC in radar, electronics, and military communications were many during the Cold War, achieved not only at Griffiss and its immediate off-site test annexes, but also at locations far removed from New York and at the test sites of military and university contractors. Radars developed through work at the RADC included:

- the AN/FPS-6 of 1951, the first long-range height finder radar incorporated into the Aircraft Control & Warning (AC&W) and SAGE air defense programs of the 1950s (see Volume I, Part IV);
- the AN/FPS-7 of 1951 for ground-controlled interception;
- the AN/CPN-18 of 1951;
- the AN/CPN-4 and AN/FPN-16 ground-controlled approach radars of 1951;
- the AN/FPS-12 low-altitude coverage radar of 1954;
- the AN/GRA-27 radar interference blanker of 1954;
- the experimental Steerable Array Radar and Communications (SARAC) program, the first electronically steerable phased-array radar of 1955—located at the Avco test site near Cincinnati;
- the AN/FPS-17 of 1955-1956, a high-powered long-range tracking radar tested for the RADC at a site in Laredo, Texas;

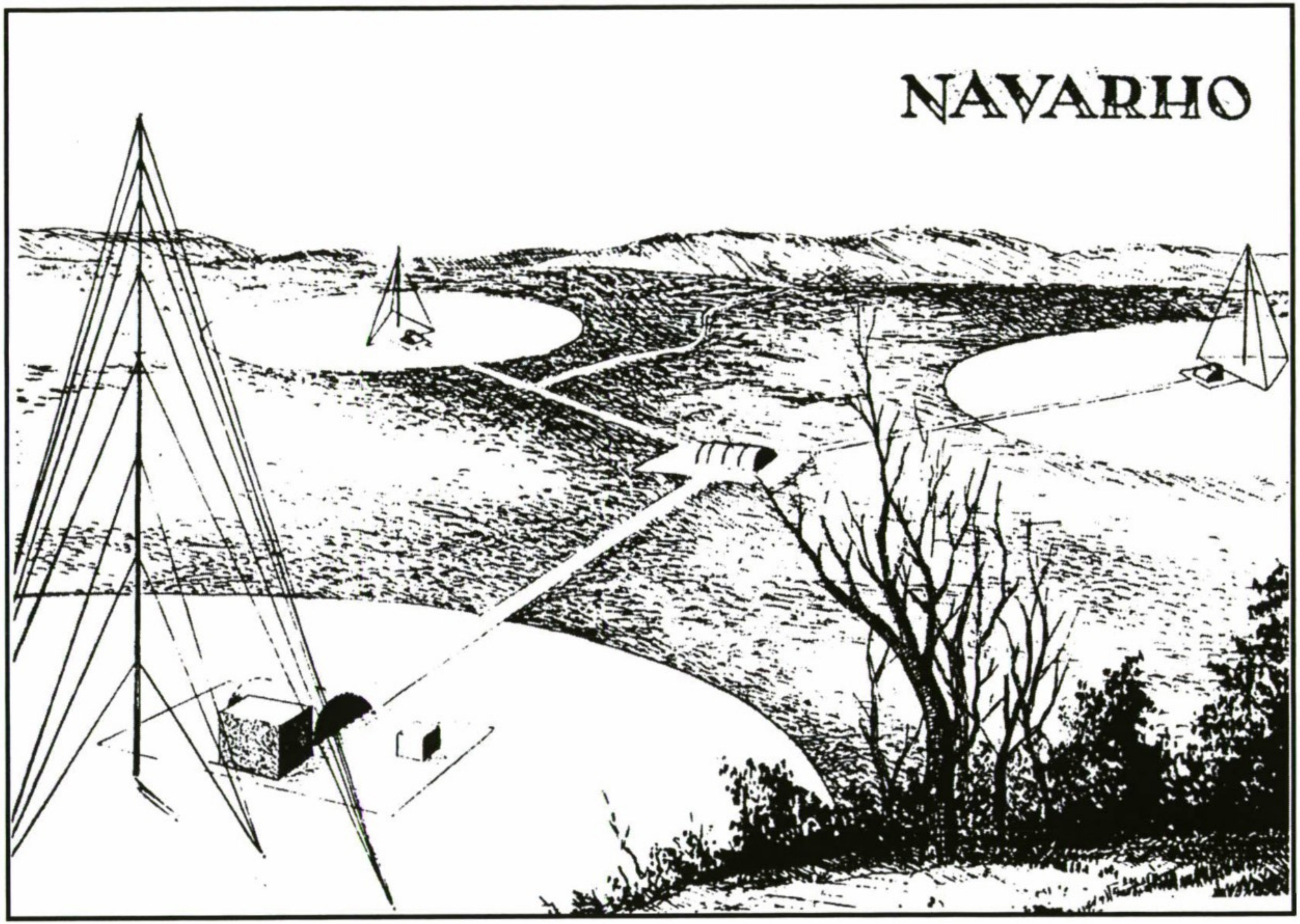

Plate 170: Navarho / Navaglobe Test Site at Camden Hill, vicinity of Frankfort, New York. In *Historical Data Rome Air Development Center 1 July – 31 December 1953*, volume 2.

- the AN/MPS-16 lightweight height finder radar for TAC of 1956;
- the AN/FPS-19 gap-filler radar for the DEW Line;
- the AN/FPS-20 air defense surveillance radar of 1956;
- the paired AN/FPS-49 and AN/FPS-50 radars for the Ballistic Missile Early Warning System (BMEWS), with a prototype site at Trinidad of 1958-1959 (see Volume I, Part IV and Volume I, Plate 113);
- the AN/FPS-46 Electronically Scanned Array Radar (ESAR) at the Bendix test site in Towson, Maryland (1958);
- the AN/FRC-56 Texas Tower radar used offshore in the Northeast in coordination with SAGE (1958);
- the AN/FPS-24, AN/FPS-26, AN/FPS-27, AN/FPS-28, and AN/FPS-35 frequency diversity radars for SAGE, beginning in 1959 and continuing through the 1960s;
- the AN/FPS-85 large phased-array radar at Eglin (in 1962-1969) (see Volume I, Part IV, Plate 116 and Volume II, Chapter 4);
- the Pincushion and Rampart missile radars at the White Sands Proving Ground, of 1958 and 1963;
- efforts toward OTH radar beginning in the late 1950s;
- overland radar research during the 1960s, contributing to the development of the Airborne Warning and Control System (AWACS);
- a prototype high-resolution large phased-array radar for ballistic missile defense, the Advanced Design Array Radar (ADAR) sited at on the Kwajalein Atoll in the Marshall Islands, erected as a part of the Advanced Research Projects Agency's (ARPA's) Project Defender of 1968-1970;
- the Cobra Dane large phased-array radar (AN/FPS-108) in the Aleutians of 1972-1977;
- the Perimeter Acquisition Vehicle Entry Phased-Array Warning System (PAVE PAWS) large phased-array radar (AN/FPS-115 and AN/FPS-123) erected at four locations in the continental United States during 1975-1987;
- support of the Space and Missile Systems Organization (SAMSO) at Los Angeles Air Force Station for space-based radar; and,
- work with the ESD at Hanscom on the ship-based large phased-array radar Cobra Judy (AN/SPQ-11) in 1978, among other radar projects.[86]

Many of these radars were associated with major Cold War programs and achievements. In 1960, the fixed-fence AN/FPS-17 in Laredo, erected to track missile launches at White Sands Proving Ground, was the first radar also able to routinely track in space. The Laredo radar had tracked Sputnik II in November 1957. The Air Force upgraded its capabilities to track artificial satellites for Project Harvest Moon. Laredo's AN/FPS-17 was a vital station employed during the Cuban missile crisis in 1962, called into service along with the long-range tracking radars in Thomasville, Alabama, and Moorestown, New Jersey, to monitor possible intermediate and medium range ballistic missile (IRBM / MRBM) launches from Cuba toward the United States. The Thomasville radar was the test site for the RADC's prototype AN/FPS-35 radar, while Moorestown was the test site for the center's AN/FPS-49. The Air Force later operated the Laredo, Thomasville, and Moorestown radars in conjunction with Eglin's AN/FPS-85 for early sea-launched ballistic missile (SLBM) tracking during the late 1960s and 1970s (as a stopgap measure until development of the PAVE PAWS).[87] The Cobra Dane intelligence radar on Shemya Island in the Aleutians replaced an AN/FPS-17 there in the early 1970s and continued in 1999 as one of 10 large phased-array American radars. The AN/FPS-85, built during the 1960s but not on line until late in the decade, is another major large phased-array radar developed through the RADC, and remains operational. Both Cobra Dane and the AN/FPS-85 contributed spacetracking information as a part of the Space Detection and Tracking System

(SPADATS) overseen by the North American Air Defense Command (NORAD) (see Volume I, Part IV).

Other important R&D milestones of the RADC were:

- the successful application of traveling wave tube (TWT) technology to radar systems to amplify radar signals (in 1954);
- work toward a ballistic missile defense system through the University of Michigan's Wizard program (in 1955);
- studies toward the WACS tropospheric network in Alaska (in 1955-1957);
- Navarho testing for global long-range navigation (in 1955-1957);
- work toward an automated Russian-English translation device (in 1957-1964);
- efforts coordinated with the ESD at Hanscom for BUIC (during the 1960s) (see Volume I, Part IV and Volume II, Chapter 5);
- support for the Vietnam War effort, beginning in 1965—including Project Underbrush on 64 square miles of range lands at Eglin (see Volume II, Chapter 4);
- work on an air defense ground environment for Japan in the late 1960s (see Volume I, Part IV);
- an automated English-to-Vietnamese translation of technical orders and manuals in 1970-1972;
- contributions toward the Advanced Airborne Command Post in 1974;
- Chinese-English and German-English automated translation devices in 1975;
- electronic warfare training for Iran (Peace Owl) in 1976;
- a remote site security sensor system for MX missile sites in 1980;
- airborne satellite communications terminals for the Military Strategic Tactical and Relay Satellite System (MILSTAR) program in 1982; and,
- electronics devices augmenting TAC's Green and Blue Flag exercises at Eglin in the late 1980s (see Volume II, Chapter 4).[88]

Again, these missions are only highlights of many more significant electronics achievements.

As of the middle 1950s, major changes in both host and tenant commands at Griffiss, and organizational shifts for the RADC within its Air Force structure, continued to crystallize. In mid-1954, Air Materiel Command (and subsequently, AFLC) became the host at the installation, with the ROAMA in place the next year. Griffiss continued as a designated major depot of the command into 1967. In late 1956, efforts for a new 11,800- by 300-foot reinforced concrete runway were underway in preparation for the arrival of SAC.[89] In August 1958, SAC placed a strategic wing on alert at Griffiss and occupied a very large area of the base from this date forward (see Volume I, Part IV). In 1970, SAC became base host, continuing in this role through the end of the Cold War (Plate 171). The RADC sustained strong links to the Cambridge Research Center (subsequently, Cambridge Research Laboratories, and later as consolidated within the AFRL) from its designation in 1951 into the present. In July 1960, the Air Force reassigned the RADC from ARDC to the AFCCDD at Hanscom, the next year to ESD at Hanscom (under AFSC), and in early 1962 directly to AFSC. In spring 1964, AFSC again considered moving ESD from Hanscom to Griffiss, reflecting the installations' sustained ties. The major organizational change in the relationship between Griffiss and Hanscom occurred in 1976, when the electronics half of the Cambridge Research Laboratories became subsumed under the RADC, a reversal of the Griffiss-Hanscom hierarchy of 1960-1962. Connections to air defense research were especially strong during the early 1950s, the late 1950s into the 1960s, and the early 1980s. ADC command posts at Hancock Field (Air Force Station) in Syracuse to the west included an ADCC in 1952 and SAGE Combat and Direction Centers in

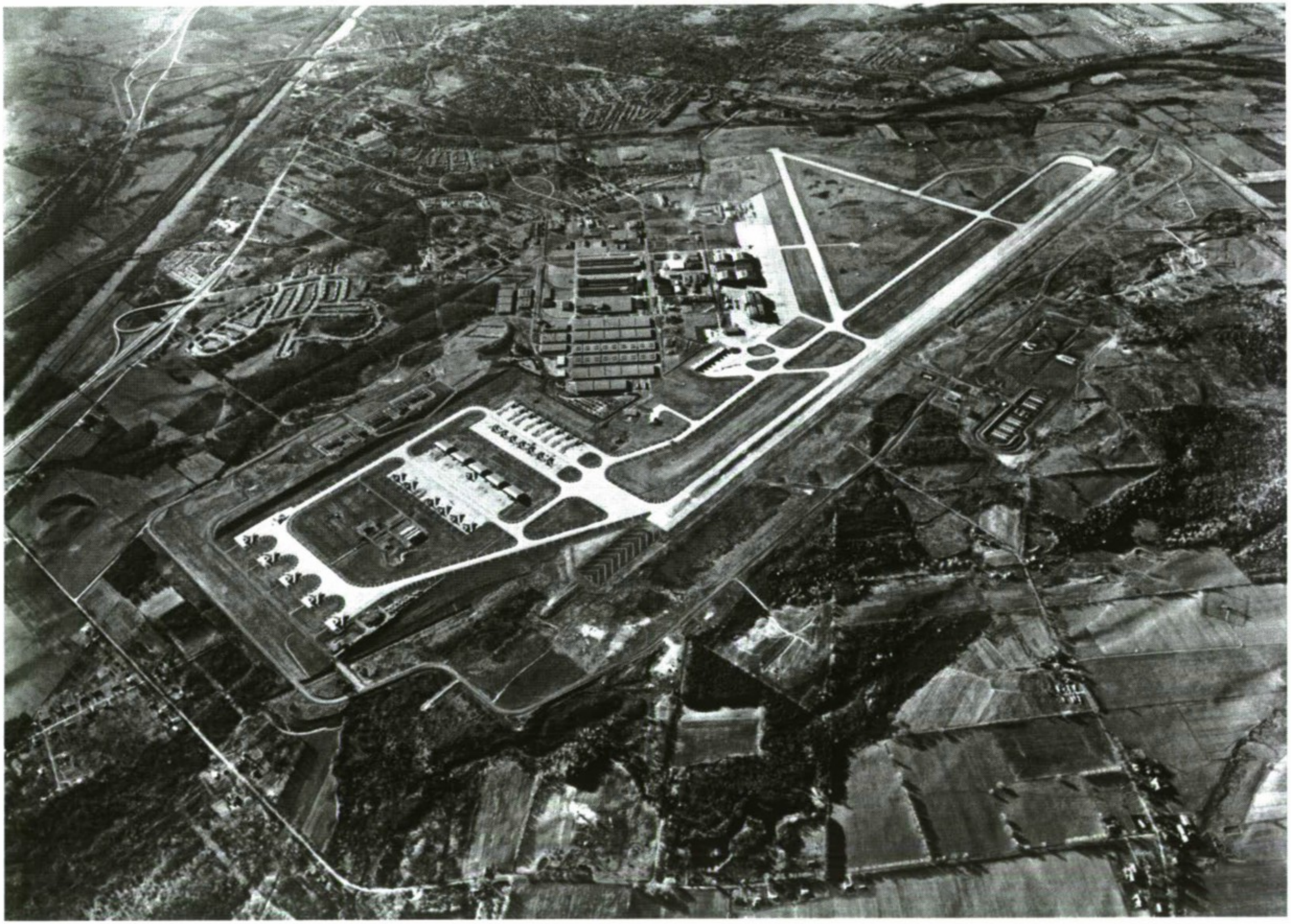

Plate 171: Griffiss Air Force Base. SAC Alert Area, middleground left. Undated photograph. Courtesy of the History Office, Rome Research Site, AFRL.

1956-1958, with third and fourth phase shakedown assignments for the overall SAGE system during the late 1950s. On Griffiss itself, an ROCC for the JSS network went in place in 1982 and is operational today. In 1997, the RADC became part of an Air Force super laboratory, the AFRL—a consolidation underway at other installations in previous years (see Volume II, Chapters 3, 5, and 8). The Rome Research Site of the AFRL and the JSS command post will be the only remaining military missions on site once the installation is fully reconfigured as the Griffiss Business and Technology Park.

Key Associated Architects and Engineers

Architectural-engineering firms of major note associated with buildings built for (or used by) the RADC at Griffiss Air Force Base included several firms that are discussed in Volume I, as noted:

- Cram & Ferguson (Volume I, Part III); and,
- L.P. Kooken (Volume I, Part II); and,
- J. Gordon Turnbull (Volume II, Part III).

Griffiss also sustained numerous structures designed by leading firms for SAC and ADC alert (see Volume I, Part IV).

---

[1] The reader can trace the broad patterns of lineage for Griffiss Air Force Base in Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). The Griffiss chapter includes the sequence of installation names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base.

[2] Lu Engineers, *Cold War Historic Building Survey Rome Research Site* (Penfield, New York: Lu Engineers for Air Force Materiel Command, November 1999), 3-27.

[3] *Ibid*, 3-26.

[4] United States Engineer Office, Binghamton District, "Air Corps Depot Rome N.Y. Illuminating Gas Distribution Schematic Plan," 31 December 1941.

[5] "Base Facilities Area Development Present Mission & VVHB Runway System," 30 March 1947, and, Air Materiel Command, "Master Plan Airfield Pavement Plan Griffiss Air Force Base," 4 February 1957.

[6] Mueller, *Active Air Force Bases*, 1989, 205-209, 224.

[7] Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999, 3-30; Air Research and Development Command, *Historical Data Rome Air Development Center 1 July – 31 December 1952*, volume 1, 20.

[8] "Base Facilities Area Development Present Mission & VVHB Runway System," 30 March 1947.

[9] *Historical Data Rome Air Development Center 1 July – 31 December 1952*, volume 1, 20.

[10] Air Materiel Command, "German Scientists," Routing and Record Sheet, 26 March 1947; "German Scientists and their Dependents Assigned to Wright Field," May 1947; W.R. Clingerman, Chief, Analysis Division, Intelligence Department, "German Scientists," 18 December 1947; and, "Temporary Duty Stations," 15 January 1948," all in Edna Jensen, *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, Study No. 215 (Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, November 1948).

[11] Air Materiel Command: "German Specialists Assigned to Wright-Patterson AF Base," 15 March 1948 and 15 July 1948, typed lists held in the Air Force Materiel Command History Office at Wright-Patterson Air Force Base; and, Air Materiel Command: "German Specialists Assigned to Wright-Patterson AF Base," 15 August 1948 and 15 October 1948, typed lists held in the History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.

[12] Air Materiel Command, "Electronic Subdivision Facilities Required for the Five Year Program," typescript, dated through internal references to ca. July 1946.

[13] Thomas W. Thompson, "Rome Laboratory Narrative History," typescript draft essay submitted to the History Office, Headquarters United States Air Force, 17 January 1996, 3-5.
[14] Radar-electronics designations contain encoding that identifies the equipment in detail. The "AN" is a joint military designation for "Army-Navy" found in all radar and similar equipment. ("AN" is sometimes omitted in the name of the equipment, but is always implied. For example, "FSS-7" is the same as "AN/FSS-7.") The final three letters reference the deployment, type, and mission of the equipment. In "CPS," the "C" indicates "air-transportable" (a category later inactive); "P," "radar;" and, "S," "detection."
[15] Air Materiel Command, *Electronics Subdivision Manufacturers' Conference 26, 27, 28 June 1946 presented at Watson Laboratories, Red Bank, New Jersey*.
[16] Thompson, "Rome Laboratory Narrative History," 1996, 5-6.
[17] Air Materiel Command, *Unit History Cambridge Field Station 3160th Electronics Station 1 July – 31 December 1948*, volume 8, parts 1 and 2, 92-93, 136-137.
[18] *Ibid*, 86, 137-145.
[19] Air Materiel Command (Evelyn D. Sullivan), *Historical Data Cambridge Field Station 3160th Electronics Station 1 January – 30 June 1949*, volume 9, 145-155.
[20] *Ibid*, 155-159.
[21] Mueller, *Active Air Force Bases*, 1989, 209-210.
[22] United States Engineer Office, "Air Corps Depot Rome N.Y. Illuminating Gas Distribution Schematic Plan," 31 December 1941.
[23] "Master Plan Airfield Pavement Plan Griffiss Air Force Base," 4 February 1957.
[24] Air Research and Development Command, "Runway Extensions, Alert Hangers [*sic*] and Taxi Strip (E.A.D.F. [Eastern Air Defense Force])," 23 May 1951, from *Preliminary Master Plan Griffiss Air Force Base, June 1949 – June 1951*, in Air Research and Development Command, *Historical Data Rome Air Development Center 1 July – 31 December 1953*, supplement.
[25] *Historical Data Cambridge Field Station 3160th Electronics Station 1 January – 30 June 1949*, volume 9, 72-73.
[26] "Building 119," inventory form in Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999.
[27] Research on the General Electric Test Operations Building in Syracuse is minimal.
[28] "Rome Expands Role of Ground Avionics," *Aviation Week* 59, 7 (17 August 1953): 274.
[29] R.F. Nicholson, *Technical Progress Report Number Ten to the Steering Committee from Data Utilization Laboratory*, December 1949, in Air Materiel Command (Evelyn D. Sullivan), *Historical Data Air Force Cambridge Research Laboratories 3160th Electronics Group 1 July – 31 December 1949*, volume 10.
[30] See Note 29. The AN/FSQ-7 and AN/FSQ-8 derived from the XD-1 and both are designated as electronics-radar equipment. The "F" indicates "fixed;" "S," "special equipment;" and, "Q," "a special purpose use."
[31] "Control Center TPI Data Utilization (Dev of PPI Project Plotting Equipment)," project summary presented at the "AMC Development Program of Electronic Equipment and Systems for Air Defense 6 – 7 July 1950," in 3151st Electronics Group, Watson Laboratories, *Review of the Watson Laboratories' Development Program of Electronic Equipment and Systems for Air Defense (Prepared for 6 – 7 July 1950 Conference at the Griffiss Air Force Base)*, 3 July 1950.
[32] "Application of Human Engineering to Information Center Design," project summary presented in *ibid*.
[33] "Development of SAGCI Components," project summary in *ibid*; Karen J. Weitze, *Cold War Infrastructure for Air Defense: The Fighter and Command Missions* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 90-92; and, Air Research and Development Command, *Historical Data Rome Air Development Center 1 July – 31 December 1951*, volume 2, appendix 5.
[34] Thompson, "Rome Laboratory Narrative History," 1996, 6-7.
[35] "Rome Expands Role of Ground Avionics," *Aviation Week*, 17 August 1953, 277.
[36] Air Research and Development Command, *Historical Data Rome Air Development Center 3 April – 30 June 1951*, 61-62, 66-67.
[37] John F. Corso, Carlo P. Crocetti, and Donald E. Page, Human Factors Office, Electronic Development Division, *Human Engineering Evaluation of the Rome Air Development Center Experimental Operations Room*, RADC Technical Report 52-27, December 1952, in *Historical Data Rome Air Development Center 1 July – 31 December 1952*, volume 2.
[38] Watson Laboratories, "Minutes Data Transmission Meeting with Tactical Air Command 16 and 17 September 1948."

---

[39] Philip Klass, "Rome Guides AF Avionics Development," *Aviation Week* 59, 7 (17 August 1953): 251.
[40] Air Research and Development Command, *Historical Data Rome Air Development Center 1 January – 30 June 1953*, supplement, 78.
[41] Air Materiel Command, "Basic Layout Plan Griffiss Air Force Base," 4 February 1957, and, Directorate of Installations, "Griffiss Air Force Base," Master Plan, 1 October 1957.
[42] *Historical Data Rome Air Development Center 1 July – 31 December 1951*, volume 2, 3-7, and appendix 53.
[43] Historic buildings inventories for the former Griffiss Air Force Base are useful in an analysis of past missions, but typically do not have sufficient contextual cross-referencing to acknowledge which buildings are key across the Army Air Forces or which have a major architect or engineer involved in their baseline design. In almost all cases, discussion of Cold War missions in World War II buildings is minimal. Air Force Materiel Command also hired a series of cultural resource firms to carry out its historic buildings inventory, with later firms reusing parts of earlier work *verbatim* (without crediting the preexisting documents), and with significant confusion regarding National Register of Historic Places evaluations. The sequence of studies is: Tetra Tech, Inc., and Thomason and Associates, *Historic Structures Survey Griffiss Air Force Base* (San Bernardino, California, and Nashville, Tennessee: Tetra Tech, Inc., for Air Force Materiel Command through the Air Force Center for Environmental Excellence, October 1995); Joseph Trnka, Heather Puckett, Charles Arthur, and Mary Sayers, for Earth Tech, Inc., and Woodward-Clyde, *Historic Building Inventory*, Draft, volumes 1 and 2 (Colton, California: Earth Tech, Inc., July 1998); and, Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999.
[44] Klass, "Rome Guides AF Avionics Development," *Aviation Week*, 17 August 1953, 258-260.
[45] Air Research and Development Command, *Historical Data Rome Air Development Center 1 January – 30 June 1952*, volume 2, 10; "Building 106," inventory form in Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999.
[46] Cram & Ferguson, "Air Force Bedford Research Center Air Defense Laboratory Building C," drawing 35-06-02, 28 December 1951, revised 24 October 1952 by Alexander D. Crosett & Associates for Griffiss Air Force Base Laboratory.
[47] L.P. Kooken, "Special A.M.C. Warehouse," April 1952, revised 15 October 1952 by Alexander D. Crosett & Associates for Griffiss Air Force Base Ground Electronics Storage Building.
[48] United States Army Corps of Engineers, New York District, "Special AMC Warehouse Completed Ground Electronic Storage Building Girder Cracks in North Bay Survey of Cracks Made 18, 19 April 1957," 23 April 1957, and, Ammann & Whitney, "Griffiss Air Force Base Special A.M.C. Warehouse Building No. 3 – Frame Repairs," 1 May 1957.
[49] "Building 3," inventory form in Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999.
[50] John Q. Smith and David A. Byrd, *Forty Years of Research and Development at Griffiss Air Force Base June 1951 – June 1991*, RL-TR-92-45 In-House Report (Griffiss Air Force Base: Air Force Systems Command, ca.1991-1992), 91.
[51] *Historical Data Rome Air Development Center 1 January – 30 June 1952*, volume 2, 8-9.
[52] *Ibid*, 20-22, appendix 22.
[53] *Historical Data Rome Air Development Center 1 July – 31 December 1952*, volume 2, 14 and 16.
[54] *Historical Data Rome Air Development Center 1 January – 30 June 1953*, supplement, 75-79.
[55] Air Materiel Command, "Basic Layout Plan Griffiss Air Force Base," 4 February 1957. This rare map specifically identifies the locations of Sites 1A, 1B, 2, 3, 4, 5, 6, 8A, 9, 10, 11, 12, 13, and 14. Sites 8 and 9A are also easily discerned due to their textual description in *Historical Data Rome Air Development Center 1 January – 30 June 1953*, supplement, 75-79. Site 9A is mapped as an open storage area by 1957, shown with a surrounding fence (the former POW camp of World War II). Site 8 is identified as the "CRD-6 Site" on the map.
[56] These two radars are designated as CPN and TPS units. The "CPN" encoding indicated an "air-transportable" [C], "radar" [P] that functioned as a "navigational aid" [N]—such as altimeters, beacons, compasses, racons, and depth sounding, approach, and landing instruments. "TPS" signified a "transportable, ground-use" [T] radar [P] with a "detection" [S]mission.
[57] "MPN" indicated a "mobile, ground use" [M] radar [P] used as a navigational aid [N].
[58] These two equipment designations are not entirely clear. "CRD" is likely an "air-transportable" [C], "radio" [R], "direction finder" [D]. Similarly, "GRD" is likely a "general ground use" [G], "radio" [R] "direction finder" [D].

[59] George Cully, History Office, Air Force Research Laboratory, Wright-Patterson Air Force Base, 55-page typescript list of numbered MX projects, MX-1 to MX-2276. Work in progress, as of 21 November 2000.
[60] "MSQ" stood for a "mobile, ground use" [M], special or combined piece of equipment [S], used for "special or combined purposes" [Q].
[61] "FPN" indicated a "fixed" [F] "radar" [P] used as a "navigational aid" [N].
[62] A large section, "Avionics in the Air Force," within the *Aviation Week* issue of 17 August 1953 devoted to ARDC, includes several looks at RADC, with discussion also of related avionics R&D at the Cambridge Research Center. The GCA turntable is featured on pages 286, 290, and 292.
[63] The CW-209 / CPN-6B was an "air-transportable" [C], "control" [W] device. See note 14.
[64] "Development of Standard Radomes for Ground USAF Radar Equipments," project summary presented in *Review of the Watson Laboratories' Development Program of Electronic Equipment and Systems for Air Defense (Prepared for 6 – 7 July 1950 Conference at the Griffiss Air Force Base)*, 3 July 1950.
[65] "Standard Radome for Ground Radar Equipments," 30 June 1952, *Historical Data Rome Air Development Center 1 January – 30 June 1952*, volume 2, appendix 23.
[66] *Historical Data Rome Air Development Center 1 January – 30 June 1953*, supplement, 38-41.
[67] Air Materiel Command, "Master Plan Off-Base Facilities Griffiss Air Force Base," 4 February 1957.
[68] Air Materiel Command, "Master Plan Forestport Site Griffiss Air Force Base," 4 February 1957; Thomas W. Thompson, "Forestport Test Annex," in Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999, 3-51 – 3-52.
[69] *Historical Data Rome Air Development Center 3 April – 30 June 1951*, 61.
[70] *Historical Data Rome Air Development Center 1 January – 30 June 1953*, supplement, 68-70.
[71] *Historical Data Rome Air Development Center 1 January – 30 June 1952*, volume 2, 9.
[72] Air Materiel Command, "Master Plan Verona Site Griffiss Air Force Base," 4 February 1957.
[73] Thomas W. Thompson, "Verona Test Annex," in Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999, 3-52 – 3-57.
[74] Klass, "Rome Guides AF Avionics Development," *Aviation Week*, 17 August 1953, 258.
[75] *Historical Data Rome Air Development Center 1 January – 30 June 1953*, supplement, 73.
[76] Smith and Byrd, *Forty Years of Research and Development at Griffiss Air Force Base June 1951 – June 1991*, ca.1991-1992, 118.
[77] Thomas W. Thompson, "Newport Test Annex," in Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999, 3-57 – 3-60.
[78] The AN/GRC-27 was a ground-to-air radio. The "GRC" stood for "ground use, general" [G], "radio" [R], "communications" [C].
[79] Thomas W. Thompson, "History of Test Annexes," in Lu Engineers, *Cold War Historic Building Survey Rome Research Site*, 1999, 3-47 – 3-64; Tetra Tech, Inc., and Thomason and Associates, *Historic Structures Survey Griffiss Air Force Base*, 1995, 5-54 – 5-65; Air Force Systems Command, "Experimental Sites," *Rome Air Development Center 1951-1971*, ca.1972; and, Air Materiel Command, "Master Plan Off-Base Facilities Griffiss Air Force Base, 4 February 1957.
[80] Smith and Byrd, *Forty Years of Research and Development at Griffiss Air Force Base June 1951 – June 1991*, ca.1991-1992, 106.
[81] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), *passim*.
[82] Air Research and Development Command, *Historical Data Rome Air Development Center 1 July – 31 December 1953*, supplement, appendix 70.
[83] Smith and Byrd, *Forty Years of Research and Development at Griffiss Air Force Base June 1951 – June 1991*, ca.1991-1992, 25, 29.
[84] *Historical Data Rome Air Development Center 1 January – 30 June 1953*, supplement, 72-73; "Rome Expands Role of Ground Avionics," *Aviation Week*, 17 August 1953, 296-297.
[85] Smith and Byrd, *Forty Years of Research and Development at Griffiss Air Force Base June 1951 – June 1991*, ca.1991-1992, 13.
[86] *Ibid, passim*; David F. Winkler, *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program* (Champaign, Illinois: the United States Army Construction Engineering Research Laboratories, for Air Combat Command, June 1997); and, Thomas W. Thompson, *RADC History Highlights 1951-1986* (Griffiss Air Force Base: Air Force Systems Command, 1986). Radar and related electronics equipment designations not previously referenced include "FPS," "GRA," MPS," "FRC," and "SPQ." These break down

as: "FPS": fixed / radar / for detection; "GRA": ground use / radio / *undetermined*; "MPS": ground use, mobile / radar / for detection; "FRC": fixed / radio / receiving (passive detection); "SPQ": shipboard / radar / for special or combined purposes.

[87] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 212-217.

[88] Smith and Byrd, *Forty Years of Research and Development at Griffiss Air Force Base June 1951 – June 1991*, ca.1991-1992, *passim*; Thompson, "Rome Laboratory Narrative History," 1996.

[89] Air Force Systems Command, *50 Years of Excellence Griffiss Air Force Base*, ca.1992; Directorate of Installations, "Griffiss Air Force Base," 1 October 1957.

Chapter 13: Tinker Air Force Base

Historic Missions of the Cold War

Tinker Air Force Base served within Air Materiel Command / Air Force Logistics Command (AFLC) as a depot for the overhaul, repair, and modification of aircraft, engines, and selected guided missiles, with responsibilities for air freight and supplies as the Oklahoma City Air Materiel Area (AMA). The base dates to the 1940s. The Army had chosen Oklahoma City over Muskogee, Oklahoma, and Wichita, Kansas, and initiated construction for the Midwest Air Depot in 1941. The depot was operational in late 1942. Immediately adjacent to the depot—literally on the other side of the runway—the Army Air Forces approved the siting of the Douglas aircraft manufacturing plant for the C (cargo) -47. Designed by the Austin Company, the plant was one of the later World War II facilities and was of blackout type. Designated as Modification Center No. 17 in 1943, the Douglas plant would become integrated into Tinker Air Force Base after the war. As was the case for several of the Air Technical Service Command depots, Tinker supported atomic testing in the Pacific during 1945-1946, but ceased to have a substantial role in nuclear weapons development after the early 1950s. Personnel at Tinker modified the B (bomber) -29, B-50, and the earliest B-36 to carry these weapons. Two later nuclear weapons missions included the Atomic Strike Recording System and systems support management for the 477 Nuclear Detection System.

From the 1950s through 1991, Tinker maintained primary overhaul, repair, and modification responsibilities for the B-47, the B-52, and the KC (tanker cargo) -135, as well as for other aircraft. The B-47 mission focused on repair (1953-1959) and modification (1956-1969) of the bomber. The B-52 and KC-135 missions were the longest in duration, continuing until the end of the Cold War. Early in the conflict, from 1949 into 1951, the installation functioned as a supply base for B-36 parts, and was the prime maintenance facility for the B-36. By mid-1951, the B-36 mission had begun shifting to Kelly Air Force Base in San Antonio. The depot at Tinker received key specialty modification missions for unique aircraft, such as the KC-135 Strategic Air Command (SAC) command post aircraft, the E (electronics) -4 airborne warning and control aircraft, and the EC (electronics cargo) -135N Apollo Range Instrumentation Aircraft (ARIA). Throughout the Cold War, Tinker sustained a significant engine overhaul mission and became an all-jet engine facility in January 1953. In addition to aircraft and engine missions, the installation also modified and program-managed selected guided missiles, with a focus on guidance and control systems. The two major missiles systems at Tinker during the 1960s into the 1970s were the Guided Air Missile (GAM) -77 (Hound Dog) and the GAM-72 (Quail). Tinker was responsible for the demilitarization program for these systems, as well as for their active-life overhaul. During the 1970s and 1980s, AFLC assigned the base missions related to the equally significant Short-Range Attack Missile (SRAM) and the Air-Launched Cruise Missile (ALCM). The Hound Dog, Quail, SRAM, and ALCM were missiles mated to the B-52, a bomber in long-term assignment to Tinker. Other tasks at Tinker derived from the Air Force Ballistic Missile Division (AFBMD) and its follow-ons in Los Angeles (see Volume II, Chapter 9). Examples of this kind of mission included an assigned responsibility for the manned spacecraft project, the Dyna-Soar, and program management for the Defense Satellite Communications System (DSCS). Participation in efforts related to the National Aeronautics and Space Administration (NASA) were relatively minimal on base, but did include work on the EC-135 ARIA (see Volume I, Part IV). Tinker additionally maintained electronic communications missions. The base inherited several of these from the Rome AMA at Griffiss Air Force Base in New York.

Tinker sustained a long-lived and changing air defense tenant mission at an off-base annex, Area D. By 1970, Area D became the physical location for a major communications-intelligence mission through the Ground Electronics Engineering Installation Agency (GEEIA). At Tinker, GEEIA evolved into the Southern Communications Area (SCA), a subcommand of the Air Force

Communications Command (AFCC), and in 2000 was configured as the Engineering Installation Group.

Primary Missions

The primary Cold War missions of Air Materiel Command / AFLC at Tinker Air Force Base included:

- overhaul of B-29s for atomic testing in the Marshall Islands;
- production of the radio-controlled target aircraft drone the PQ (pursuit drone) -14;
- aircraft repair and modification, including the AT (advanced trainer) -6, B-29, P (pursuit) -80, P-47, P-84, B-36; B-45; B / RB (reconnaissance bomber) -47, B-50; B-52, C-54, C-135, KC-97, KC / RC (reconnaissance cargo) -135, EC-135, L (liaison) -4, L-5, L-7, VC (staff administrative cargo) -137 (the Presidential aircraft fleet), A (attack) -7, F (fighter) -4, B-1, and F-15 (aircraft components only);
- special modification of the B-29, B-50, and B-36 to carry atomic bombs;
- special modification of five KC-135s for SAC's airborne command post operation Looking Glass;
- management of the E-4 national emergency airborne command post aircraft;
- management of the EC-135 command post aircraft;
- aircraft and missile engine overhaul and repair;
- air freight responsibilities;
- bombsight repair;
- responsibility for the Oklahoma City GEEIA Region;
- management of selected guided missiles, including the Hound Dog (GAM-77), Quail (GAM-72), ALCM (the Air-to-Ground [AGM] -86B) (systems management during development), and Ground-Launched Cruise Missile (GLCM) (Ballistic Guided Missile [BGM] –109);
- repair and overhaul of the guidance and flight control systems for the Hound Dog;
- program manager for the DSCS wideband transmission service;
- storage of prefabricated steel aircraft shelters for Concrete Sky, 1970-1971;
- reclamation efforts for the GAM-77 and the GAM-72 as a part of the demilitarization of the missiles;
- systems support management for the 481L Post-Attack Command and Control System;
- systems support management for the Atomic Strike Recording System;
- systems support management for the 477 Nuclear Detection System;
- systems support for the 492L United States Strike Command Airborne Communications Center / Command Post Package;
- system program manager for the Airborne Command Post System;
- communications systems projects taken over from the Rome AMA after that depot's closeout;
- responsibility for the North American Air Defense Command (NORAD) Cheyenne Mountain Complex Communication Electronic System; and,
- aircraft repair support in Southeast Asia during the Vietnam War.

Tenant Organization Missions

Tinker hosted several significant and complex air defense tenant missions on base during the Cold War. These missions were associated with Air Defense Command (ADC), NORAD, Tactical Air

Command (TAC) and the Navy, and were in place from 1950 through the end of the conflict:

- an Air Defense Control Center (ADCC) and Air Defense Direction Center (ADDC) for the 33rd Air Division (Defense);
- a manual Semi-Automatic Ground Environment (SAGE) Direction Center for the 32nd Air Division (SAGE);
- a NORAD control center for the 32nd NORAD Region;
- a Back-Up Interceptor Control (BUIC) station;
- the 552nd Airborne Warning and Control (AWAC) Wing (the "airborne" BUIC); and,
- an Airborne Command and Control Squadron (ACCS) EC-130 wing, followed by a Navy E-6A wing.

Tinker supported NASA in one specific instance:

- the special modification of eight EC-135N ARIAs as communication links aircraft for NASA spacecraft (including associated work on communications equipment in the Apollo spacecraft, the NASA ground control center in Houston, and communications relay stations).

Other tenants of a more routine nature included Military Air Transport Service (MATS) and a 1950s tactical fighter wing. Plans at the outset of the 1950s for an ADC alert fighter-interceptor squadron (FIS) at Tinker did not materialize.

Chronology

From its beginnings in the early 1940s, Tinker served as an aircraft and weapons systems depot, with no change in basic mission throughout the Cold War. During late 1940, representatives of the Oklahoma City Chamber of Commerce had initiated lobbying efforts for the siting of a War Department aircraft factory. Nearly simultaneously, the Army Air Corps looked at the area for possible location of a Midwest air depot. The city sought the more permanent of the two facilities, perceived to be the depot. While competing with other locations, Oklahoma City did have a significant advantage and became the selected site as of spring 1941. The first name for the installation was the Midwest Air Depot (21 May 1941).[1] Construction for the base was underway in July. Once Oklahoma City secured the Air Corps depot, efforts continued toward an aircraft plant. In October 1941, Oklahoma City became a top choice for one of five desired new plants. The War Department had established the greatest proportion of aircraft, engine, and propeller plants during 1940 into early 1941, but final stages for plant buildout waited until late 1941 into 1942[2] (see Volume I, Part II). In early 1942, representatives from Douglas Aircraft visited the Midwest Air Depot to consider siting a contiguous aircraft plant. While the city had lobbied for a bomber manufacturing plant, Douglas informed Oklahoma City officials that its desires were for a cargo aircraft facility. By early 1941, the War Department had four bomber plants[3]: in Omaha (Government Aircraft Plant [GAP] No. 1), Kansas City (GAP No. 2), Tulsa (GAP No. 3), and Fort Worth (GAP No. 4).

The War Department maximized its production of Consolidated Aircraft's B-24 bomber and significantly supported the company overall. Consolidated (to become Convair) built B-24s at its San Diego plant, setting up a second B-24 assembly line in Fort Worth and a third in Tulsa—the latter managed by Douglas Aircraft. The B-24 plant in Tulsa was under construction in December 1941 as a government-owned, contractor-operated (GOCO) facility. The United States Engineer Office of the Army hired the Austin Company of Cleveland to design and build the Tulsa plant. During 1942, the Austin Company also received the commission for the Oklahoma City and Fort Worth plants. The three plants were each windowless, designed as "blackout" facilities to avoid aerial detection during any possible enemy overflight (see Volume I, Part II). They were nearly identical. Plant assembly

buildings were 4,000 feet long by 200 feet wide and featured a parallel lower-bay structure 4,000 by 120 feet.[4] The War Department sited its Oklahoma City aircraft plant (Building 3001), for the Douglas C-47, across the north-south runway from the Midwest Air Depot[5] (Plate 172). The GOCO number for the Oklahoma City facility is interpreted as GAP No. 17 (indicated on drawings of 1943).[6] The designer of the steel-and-brick Douglas C-47 plant at the Midwest Air Depot was Albert S. Low of the Austin Company.[7]

The Army Air Forces depot formally activated in March 1942; the Douglas C-47 plant, a year later. Immediately before its opening, the Midwest Air Depot took the name Oklahoma City Air Depot. In October 1942, the depot also became known as Tinker Field.[8] Work on aircraft at the depot began in autumn 1942. During 1943, the Oklahoma City Air Depot received the B-24 and B-17 for modification and maintenance. The base also overhauled aircraft engines. At the end of 1943, Army Air Forces Materiel Command assigned the Oklahoma City Air Depot a B-29 maintenance personnel training mission, as well as significant modification projects for the bomber.[9] As was the case at most other Materiel Command depots, infrastructure was highly standardized. Key hangars were an Airplane Repair Building, built as two outwardly facing pair of hangars bracketing a complex of shops (Building 230), and a double Transport Squadron Hangar—the latter in its revised iteration, an Operations – Transport Squadron and Flight Test Hangar (Building 240) (Plates 173-174). Other depots with this configured pairing included Rome and Warner Robins at Rome and Robins Fields in New York and Georgia. The Sacramento AMA at McClellan Field in California featured a triple Airplane Repair Building, but no Transport Squadron Hangar. At the future Wright-Patterson Air Force Base in Ohio, an Operations – Transport Squadron and Flight Test Hangar was present at Patterson Field, but was unusually separated from three Airplane Repair Buildings located at neighboring Wright Field. Materiel Command depots sometimes possessed only one hangar bay for the Airplane Repair Building (as at Kelly Field in Texas), but the four-bay configuration represented the mature pattern. Hill Field also had a four-bay Airplane Repair Building, but only a single Transport Squadron Hangar. Albert Kahn, of Detroit, designed the Transport Squadron Hangar in its earliest rendition of 1940, with the Airplane Repair Building a design of the Army Quartermaster Corps in the late 1930s.[10] Prominent New York engineer Fred N. Severud redesigned the Transport Squadron Hangar as the Operations – Transport Squadron and Flight Test Hangar in 1941 (see Volume II, Chapters 6, 7, 10, 11, 12, and 14). The Army awarded the overall contract for construction of the depot in Oklahoma City to J. Gordon Turnbull of Cleveland and Sverdrup & Parcel of St. Louis in mid-1941. Turnbull, in particular, would become a key engineer for protective construction immediately following World War II. Headquarters Air Materiel Command hired his firm in 1947-1948 to design an underground pilot plant (see Volume I, Part III). During the middle 1950s, Turnbull would also handle the blockhouse and initial launchers for the Bomarc (Boeing Michigan Aeronautical Research Center) interceptor missile (see Volume II, Chapter 4). At Tinker, the Armament, Fire Control, Supply, and Repair Building (Building 201), for work on Norden bombsights, and the Engine Test Building (Building 214), are also Turnbull's designs (standard across the Army Air Forces)[11] (see Volume II, Chapters 6, 11, and 12) (see Plates 172-173).

In June 1945, the Army Air Forces annexed the Douglas C-47 plant as part of Tinker Field, with formal jurisdiction assumed in November. The plant was no longer active. The Army Air Forces immediately adapted the assembly building for anticipated aircraft modification work. Also during 1945-1946, Tinker participated in preparing B-29s for Operation Crossroads near the Bikini Atoll in the Marshall Islands. Crossroads was the earliest of American post-war atomic tests and included major cross-agency military and scientific involvement (see Volume II, Chapter 10). Air Technical Service Command bases supported the effort nearly unanimously. In July 1946, as Crossroads concluded in the Pacific, Tinker became the Oklahoma City AMA coincident with the redesignation of the Air Technical Service Command as Air Materiel Command. The first assembly-line modification project at the installation was for the AT-6 in the former Douglas plant. By early 1947, the Oklahoma City AMA had also acquired the jet engine overhaul mission from the San Bernardino

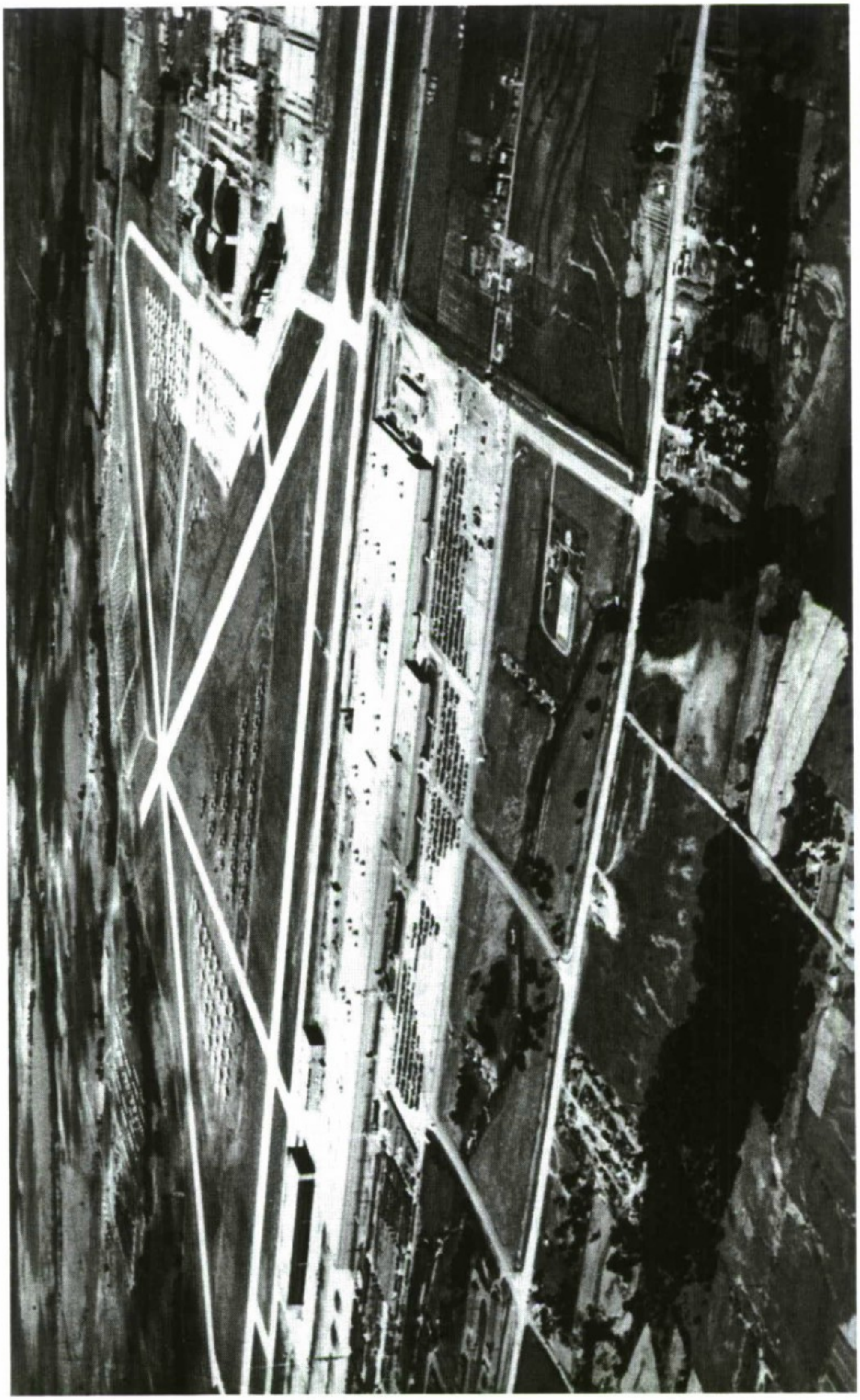

Plate 172: Aerial View of Tinker Air Force Base, 23 May 1949. Middleground: The Austin Company, Douglas Aircraft Modification Center (Building 3001), GAP No. 17, 1942-1943; Background, right: Airplane Repair Building (Building 230) and Operations – Transport Squadron and Flight Test Hangar (Building 240), 1941-1942. Kramer Collection, History Office, Tinker Air Force Base.

Plate 173: United States Army Quartermaster Corps. Airplane Repair Building (Building 230), Tinker Air Force Base, 1941-1942. Foreground, right to left: Buildings 204 and 205, 1941-1942. Undated photograph. Courtesy of the History Office, Tinker Air Force Base.

Plate 174: Fred N. Severud. Operations – Transport Squadron and Flight Test Hangar (Building 240), Tinker Air Force Base, 1941-1942. Background, left: J. Gordon Turnbull, Engine Test Cells, 1941-1942. Undated photograph. Kramer Collection, History Office, Tinker Air Force Base.

AMA at San Bernardino Army Air Field (later, Norton Air Force Base) in Southern California. In August the same year, Air Materiel Command announced that the Oklahoma City AMA would become the repair center for the B-36 bomber.[12]

The B-36 mission required particular infrastructure, typically not readily available at existing Army Air Forces installations at the close of World War II. At Tinker Field, original runway construction had been of reinforced concrete, with the northwest / southeast runway 7,842 feet long and 150 feet wide, the north / south runway 7,600 feet long and 150 feet wide, and the northeast / southwest runway 6,334 feet long and 150 feet wide[13] (see Plate 172). Although a B-36 runway, when built for that purpose in the late 1940s and early 1950s, was often 11,000 to 13,000 feet long and 300 feet wide, the northwest / southeast runway was sufficient to land the B-36 during its tenured assignment to the Oklahoma City AMA. Typically, a B-36 runway necessitated massive substructure of nearly 20 inches depth. Standard Army construction for its reinforced concrete runways of early World War II used six-by-six-inch welded wire mesh, embedded two inches below the surface—described in period engineering journals as comparable to "multiple-lane superhighway construction."[14] World War II runway substructure at Tinker Field remains only partially researched, but suggests that subsurface problems existed.[15] The Air Force appears to have handled the challenge of the B-36—a very large and heavy aircraft—in two ways: (1) engineering a fully new runway or substantially upgrading an existing runway (including lengthening) or (2) overlaying existing runways to strengthen them for short-term use. An Army Air Forces *Installations Directory* of July 1944 listed the strengths of runways at over 600 airfields, in preparation for experimentation toward post-war bombers.[16] At Tinker, engineers likely augmented the northwest / southeast runway through concrete overlays. The runway's length remained marginal for the B-36 and was the primary reason for moving the B-36 assignment to Kelly in 1951. While the same challenge existed at the San Antonio depot, Air Materiel Command could use a runway at Kelly in a short-term manner as it had at Tinker (for about four years). Both the Oklahoma City and San Antonio depots had new runways under construction in 1954 (see Volume II, Chapter 7).

Maintenance hangar space for the B-36 also posed challenges in the late 1940s for the Oklahoma City AMA. The Airplane Repair Building (Building 230) provided four aircraft maintenance docks for the B-36, but in a very tight fit. The late 1930s design of the Airplane Repair Building featured a tied steel arch, with 275-foot clearspan. The door opening across the end of the hangar was 250 feet (for the 236-foot wingspan of the B-36). Depth of the Airplane Repair Building varied at the depots, from 190 to 250 feet. The height of the hangar doors created the most immediate challenge for B-36 maintenance. Designed for the large bombers of the future, the doors permitted taller aircraft tail assemblies through the lift doors centered in each hangar bay. The uniform door height across the end facades was 37 feet. The upper lift doors (four in Tinker's Airplane Repair Building) increased the height to 52 feet in the center of each bay, 15 feet across. The B-36 tail was 49 feet tall, making this arrangement extremely close. At 162 feet long, the B-36 was fully capable of entering the Airplane Repair Building. When Air Materiel Command assigned the Oklahoma City AMA the B-36 repair mission in early August 1947, the B-36A had not yet taken its inaugural test flight. Convair delivered the first two B-36As to the Air Force in June 1948. These aircraft flew directly to Eglin Air Force Base in Florida for proof tests (see Volume II, Chapter 4). By November 1948, 22 B-36As were in Air Force hands. The B-36A was an unarmed training aircraft. Manufacture of the B-36B was nearly simultaneous with the B-36A, and at the close of 1948, SAC possessed 35 B-36s at Carswell Air Force Base in Fort Worth, Texas, adjacent to the Convair plant (Air Force Plant [AFP] 4) (see Volume II, Chapter 15).[17] The first B-36 repair at Tinker was underway in late May 1949. The Oklahoma City AMA stocked B-36 parts at the depot shortly before that date. Personnel at the depot used two bays of the Airplane Repair Building for B-36 maintenance work.[18] During 1950, men and women at the base modified B-29s, B-50s, and B-36s to carry the atomic bomb,[19] although by mid-1951 the repair mission for the B-36 shifted from the Oklahoma City AMA to the

San Antonio AMA at Kelly—where B-36 nose docks specifically accommodated the oversized bomber (see Volume II, Chapter 7). During 1950, personnel at Tinker installed parallel radar, navigation, and bombing systems on 10 B-36s (see Volume I, Part II).

During the first years of the Cold War, Tinker continued to receive traditional aircraft and engine overhaul missions. Major base expansion was underway in 1951. By the late 1940s, the Oklahoma City AMA handled a growing variety of aircraft for modification and repair, including the B-29, B-45, B-50 (adapted from the B-29), C-54, L (liaison) -5, and L-7. The former Douglas aircraft assembly plant (Building 3001) housed the B-29 and B-50 repair. Lines of aircraft moved through the structure. As of 1947, Tinker also used Building 3001 for jet engine overhaul. In mid-1950, the Oklahoma City AMA initiated operations as a freight terminal. Air Materiel Command designated Tinker as a primary supply depot in June. The command had restructured its logistics organization during 1948-1949 by establishing a two-zone system for the continental United States. Air Materiel Command assigned individual depots within each zone specific stocking responsibilities rather than general stocking at each depot. At the close of 1949, Air Materiel Command had set up eight major depots—all either continuing, or reinstated for, missions similar to those of World War II. (The Air Technical Service Command supply network had achieved a peak of 12 physical locations as primary depots, including that at Oklahoma City.) The depot in Oklahoma City had functioned without interruption after the war. The location was also one of two considered for "super AMA" status in plans of 1945 (the San Antonio AMA was the other). An emphasis on modern business methods for logistics management had surfaced as early as 1948 within Headquarters Air Materiel Command at Wright-Patterson Air Force Base. By 1950-1951, the intent was to create a warehousing system that rivaled private industry (see Volume I, Part II). The circumstances had an immediate impact on the Oklahoma City AMA.

Perhaps due to the earlier plans to make Oklahoma City a super depot, Air Materiel Command's modern warehousing program manifested results at Tinker either first for the command, or nearly so. One of Air Materiel Command's most pressing problems in 1950 was a severe deficiency in warehousing—both in terms of square footage and suitably modern structures. General Edwin W. Rawlings, as commander of Air Materiel Command at Wright-Patterson and in possession of a Harvard University Masters in Business Administration (MBA), pled his case for radically increased warehousing. The Department of Defense approved 5,696,000 square feet of new warehouse construction during Fiscal Year (FY) 1952. Efforts toward a modern warehouse specifically for Air Materiel Command were underway in early 1951. During the 1947-1950s period, civil engineering responsibilities for Air Materiel Command, and often for the larger Air Force, fell within the command in a manner paralleling the role of the Army Corps of Engineers (see Volume I, Part III). The result was a series of provocative engineering commissions, often with preliminary work toward specifications executed within the command and complemented through the full-blown development of designs contracted to major engineering firms. For the warehousing challenge, Headquarters Air Materiel Command planned a "Special AMC [Air Materiel Command] Warehouse." The very first known iteration of the warehouse—to be built across the command in standardized sizes using prefabricated components in modular units—is that of April 1951, annotated as drawing series 33-02-01 and erected at Tinker.

By the second version of the warehouse, as represented in the next drawing series (33-02-02) of April 1952, the responsible architectural-engineering firm is L.P. Kooken of Baltimore. The 1952 design is also the version that receives the formal name of "Special AMC Warehouse." The warehouse relied on modular rigid-frame, reinforced concrete construction, cast in place with continuous girders. The final version of the evolving design included two possible framing systems, three wall panel choices, and two roof slab types. The warehouse used thin-shell concrete panels in one of its variations, and was of cutting-edge engineering. Evaluated and recognized in American engineering journals, and

related to the most advanced international trends of the period, Air Materiel Command's modular warehouse did not finish construction until 1957-1958 (in the largest pair of Special AMC Warehouses erected at McClellan). Due to the experimental nature of the structure, several of the earliest warehouses suffered partial failure in the middle 1950s. Headquarters Air Materiel Command called in yet another major engineering firm, Ammann & Whitney of New York, to evaluate the problem and retroactively create a solution (carried out at most Air Materiel Command installations where the warehouse had been erected or was under construction). Size of the Special AMC Warehouse varied from 160,000 square feet to 1,500,000 square feet (the latter in the paired warehouses at McClellan). The most common standard size was 400,000 square feet. Width for the Special AMC Warehouse was always 400 feet, with varied modular length. Air Materiel Command built the Special AMC Warehouse at 20 locations, sometimes erecting two warehouses at a location (either paired or for separate uses on a base) (see Volume I, Part II; Volume II, Chapters 6, 7, 10, 11, and 13).

At Tinker, Air Materiel Command built three of the futuristic warehouses: one in 1951-1952, a second in 1953-1954, and a third in 1954-1955—also expanding the first warehouse at the time of construction for the third (sometimes referenced as a fourth warehouse for the base). The first warehouse, Building 416, is based on the 33-02-01 design of April 1951, possibly the prototype structure for L.P. Kooken's Special AMC Warehouse of April 1952. The design and engineering responsibility for the April 1951 warehouse is not fully confirmed. While the local firm of Hudgins, Thompson, Ball & Associates appears in the title blocks for the 33-02-01 drawings, the firm name also is provided for the known L.P. Kooken Special AMC Warehouses of 1952 erected at Tinker (Buildings 3705 and 412). For the L.P. Kooken drawings, fully verified for the Special AMC Warehouse of 1952 forward, Hudgins, Thompson, Ball & Associates' name is added to the title blocks for foundations and interior detail sheets (of Building 3705), leaving the L.P. Kooken name on the primary sheets. Typically when this situation occurred, the original date of the design remained on the drawings (as was the case for construction at Tinker: 29 April 1952). The date of the regional firm's adaptation of the design was then overlaid (at Tinker: 30 January 1953). Attribution of design and engineering responsibility is always difficult during this period due to the Corps of Engineers practice of providing drawings—already fully executed by a firm contracted at a national level—to local firms through its regional offices. The local firm very often replaced the responsible firm's name with its own. This working practice creates a false impression of who should be credited with what.

At Tinker the situation is further muddied. The history of the Oklahoma City AMA for the second half of 1951 suggests that Hudgins, Thompson, Ball & Associates may have actually been the designers of the April 1951 warehouse. It appears that the Air Installations (civil engineering) office at Tinker gave the firm a directive to design the warehouse, but not a set of drawings. Documented discussion implies that Hudgins, Thompson, Ball & Associates next created the basic design for the future "Special AMC Warehouse." Although the L.P. Kooken Special AMC Warehouse is much more sophisticated in its engineering than Building 416, the *idea* of a cost-effective, modular warehouse to meet Air Materiel Command needs may be that of the local Oklahoma City firm. If this is true, Building 416 is one of a kind for the command and contributed directly to a highly important program implemented nationally the next year—a program implemented even at Tinker. The Oklahoma AMA thus showcased both an unusual "prototype" stage for the Special AMC Warehouse and its standardized mature version on a single installation—and did so with three of the warehouses, the most at any Air Materiel Command installation.

> The comprehensive result of this [the initiative of the Air Installations Section at Tinker in hiring Hudgins, Thompson, Ball & Associates] is that Headquarters, United States Air Force, Office of

> the Chief of Engineers, and the Munitions Board in Washington so definitely recognized the value of the work done at Tinker that all their former policy concerning warehousing was changed. The warehouse criteria now issued from the Washington level incorporates the basic functional and design criteria established in our Area A warehouse, Building 416.[20]

The first of the three modern warehouses at Tinker was Building 416 in Area A. Air Materiel Command interpreted the design as achieving a "low cost permanent type construction [based on]...the careful evaluation of the functional requirements of the warehouse." Planning toward Building 416 began in January 1951, several months before a design existed.[21] The structural system for the warehouse is steel-frame, with interior steel girders and concrete piers.[22] Walls are concrete block. Building 416 is highly modular, but its unit system is different than the Special AMC Warehouse of 1952. The final dimensions of Building 416 are approximately 487 feet wide by 697 feet long, creating a structure of about 340,000 square feet (Plate 175). Building 416 strongly suggests an attempt to create a warehouse to meet specific Air Materiel Command needs for flexible (greater or lesser) size. Its construction featured assembly-line methods of erection reliant on standardized components. The flat, modular roof system and the use of concrete block, also foreshadowed the choices available for the Special AMC Warehouse of the next year. The three variations in wall treatment for the Special AMC Warehouse were a combined masonry (hollow tile or concrete block) and poured-in-place concrete; poured-in-place concrete; and, precast concrete panels. Roof slabs for the 1952 warehouse were either precast plank or thin-shell, precast ribbed slab[23] (see Volume I, Part II). In November 1954, Air Materiel Command planned to add a 77,534-square-foot addition to the north end of Building 416, "of reinforced steel and concrete in order to match the existing structure."[24] The addition was modular, achieving precisely the expansion sought through the design of the Special AMC Warehouse effort (see Plate 175).

Almost as soon as workers completed construction for Building 416, the Oklahoma City AMA added a second warehouse near the former Douglas aircraft plant. By late July 1951, the Oklahoma City AMA planned to build a warehouse for Area C—first intending a then-standard, woodframe Corps of Engineers structure. As a result of the success of Building 416's presentation to Headquarters Air Materiel Command at Wright-Patterson, and thence to Headquarters Air Force, Air Materiel Command changed the design directive for an Area C warehouse, stipulating that it conform with "the new standard depot type warehouse plan [represented in Building 416]." The "new standard depot type warehouse" was still not yet the design of L.P. Kooken, but by mid-December 1951 had become a formal intention of the command for a warehouse of 400 feet width and 1,000 feet length.[25] The Oklahoma City AMA did not proceed with the erection of its second modern warehouse in Area C (Building 3705) until January 1953—a gap of over a year from the stated plans of Air Materiel Command.[26] By that date, L.P. Kooken had completed a set of drawings for the Special AMC Warehouse, although the full range of the basic variations for the warehouse appears to date to 1955. Construction for Building 3705 occupied 31 months, in total, with partial occupation as of August 1954 and full project completion in 1955. Employing the reinforced concrete rigid-frame system (with continuous cast-in-place girders) characteristic of the Special AMC Warehouse, Building 3705 was 60,000 square feet larger than Building 416. Wall panels featured red hollow-tile masonry and visually offered a significant departure from Building 416's concrete block finished in gunnite (Plate 176).[27] To reclaim the distinction of "biggest" for Building 416, Tinker added the north addition to Building 416 just as personnel occupied Building 3705 in late 1954. The addition to Building 416 made that warehouse the larger of the two warehouses—at 417,534 square feet.[28]

Simultaneous with the addition to Building 416 and the completion of Building 3705 during late 1954 and through 1955, the Oklahoma City AMA also erected the third of its ultra-modern warehouses,

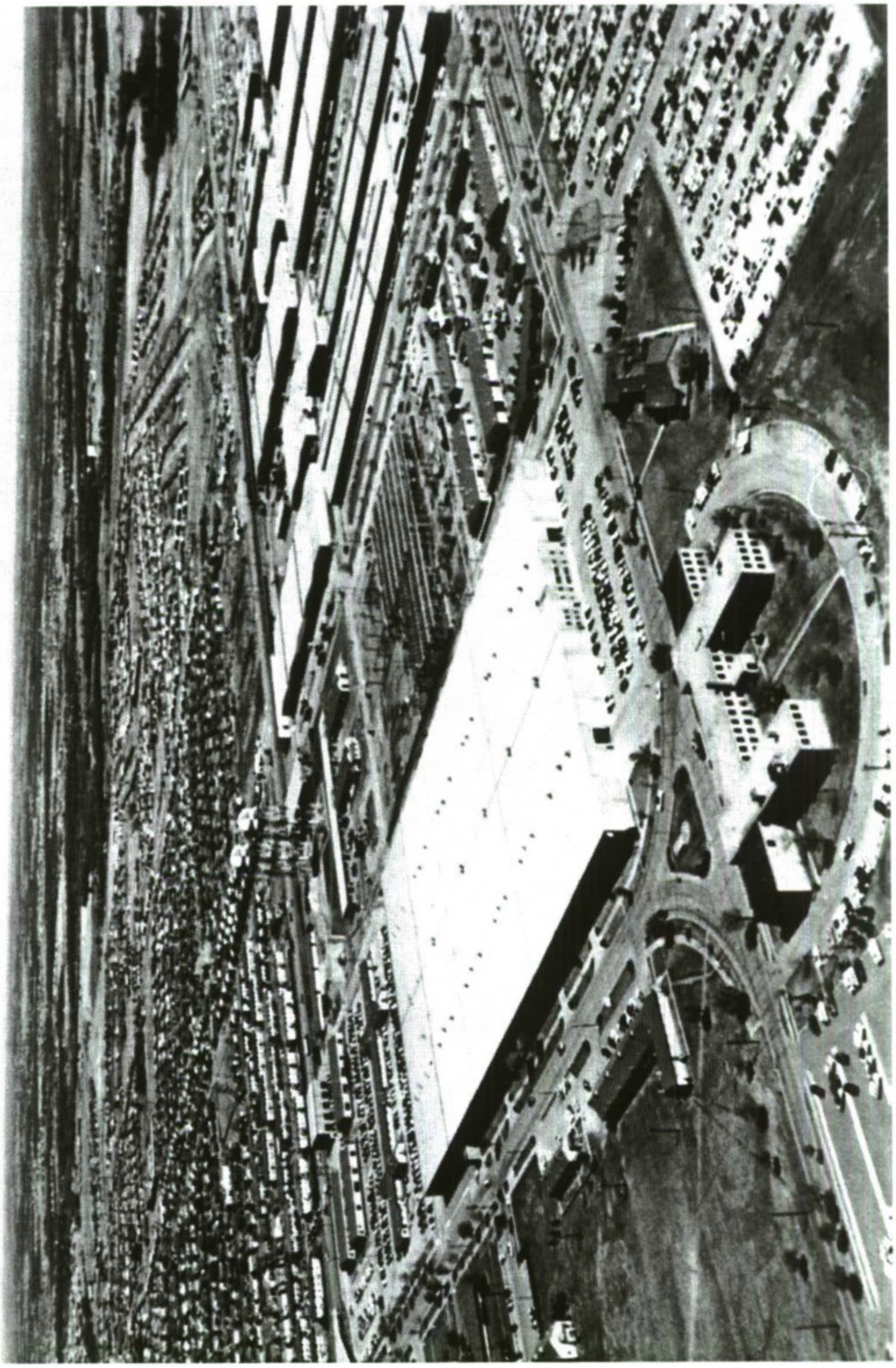

Plate 175: Hudgins, Thompson, Ball & Associates. Warehouse (Building 416), Tinker Air Force Base, 1951. With north addition of 1955. Photograph of ca.1955. Kramer Collection, History Office, Tinker Air Force Base.

Building 412. The final warehouse was another L.P. Kooken Special AMC Warehouse, 320,000 square feet in size, sited next to Building 416 in a former reclamation-salvage yard. Photographs of 1955 show Building 412 under construction and highlight the warehouse's cast-in-place, rigid-frame reinforced concrete system about halfway through erection of the structural framework for the building. By the date of the photograph (Plate 177), workers had completed the north addition to Building 416. While other Air Materiel Command depots showcased very large paired Special AMC Warehouses (at Robins and McClellan), or provided examples of unusual adaptation (for radar electronics at Griffiss and atomic weapons training materials and inert parts at Kelly), no base illustrated the command's early 1950s warehouse program to the degree found at Tinker. By late 1954, Air Materiel Command had become aware that the Special AMC Warehouse had emerging structural problems at selected depots (with cracking at Robins among the earliest reported trouble). In mid-1955, the roof on a Special AMC Warehouse at Wilkins Air Force Station in Shelby, Ohio, suffered a partial collapse. The command called in engineering consultants before the close of the year to inspect the Robins and Wilkins warehouses, and hired Ammann & Whitney in early 1956 to prepare a structural retrofit that added steel to roof girders for those warehouses not yet completed (or still ahead, as at McClellan). Ammann & Whitney's solution also applied to warehouses evaluated as failing, including Building 3705 at Tinker. Personnel had discovered roof girder cracking in Building 3705 in late August 1955, after the dramatic situation at Wilkins.[29] With the Ammann & Whitney improvement, the Special AMC Warehouse served the command well and remains an example of important experimental technology of the early 1950s sponsored by Air Materiel Command (see Volume I, Part II).

Also prominent during the early 1950s was the arrival of an ADC mission at Tinker (see Volume I, Part IV). Sited just off base and known as Area D, the air defense installation dated to the outset of the decade. Similar to the Special AMC Warehouse program at Tinker, the ADC command post in Area D was especially complete. Air Materiel Command had participated substantially in the civil engineering and programmatic design for ADC's first command post and radar system of the Cold War. The research and development (R&D) side of Air Materiel Command had begun working on the interior layout and equipment for the air defense command post in 1946, while the civil engineering office within Air Materiel Command turned to the preparation of building specifications in 1948. Air Materiel Command had hired the Chicago architectural-engineering firm of Holabird, Root & Burgee in 1949 and that firm had completed drawings for the command posts late in the year. The resulting ADCCs and ADDCs derived from a barely inaugurated air defense program of World War II for the Fighter Control Center, as well as from its related Filter and Information Centers. Holabird, Root & Burgee, with considerable participation within Headquarters Air Materiel Command, devised the Type 1-4 Operations Buildings. These structures were proto-hardened and gas-proof. The Type 1-4 Operations Buildings were interchangeable command posts from the radar station level to that of regional control for an established air defense sector. At some locations, ADC jointly sited the region's ADCC (housed in a Type 4 Operations Building) with the ADDC of an Aircraft Control & Warning (AC&W) radar station (housed in a Type 2 Operations Building). Such was the case at Tinker. Building 4020 was the ADCC of the command post, and Building 4012, the ADDC. A miniature installation of dormitory and cantonment buildings also designed by Holabird, Root & Burgee supported the ADCC / ADDC pair (see Volume I, Plate 93).

Similar to AMAs, the boundaries of air defense areas shifted radically during the 1950s, shrinking as ADC provided more ADCCs and AC&W radar coverage. Over time, defense sector numbering also changed, and tracking historic jurisdiction is replete with pitfalls. By mid-1951, ADC's air defense areas numbered 11, by 1956-1958, 16—awaiting the transition to SAGE. Predictably in the rush to achieve permanent command posts, ADCCs were often found briefly in temporary quarters—usually World War II woodframe buildings or quonset huts available at the host base. Sometimes ADC would set up an ADCC in an ADDC at another regional military base (Air Force, Army, or Navy) due

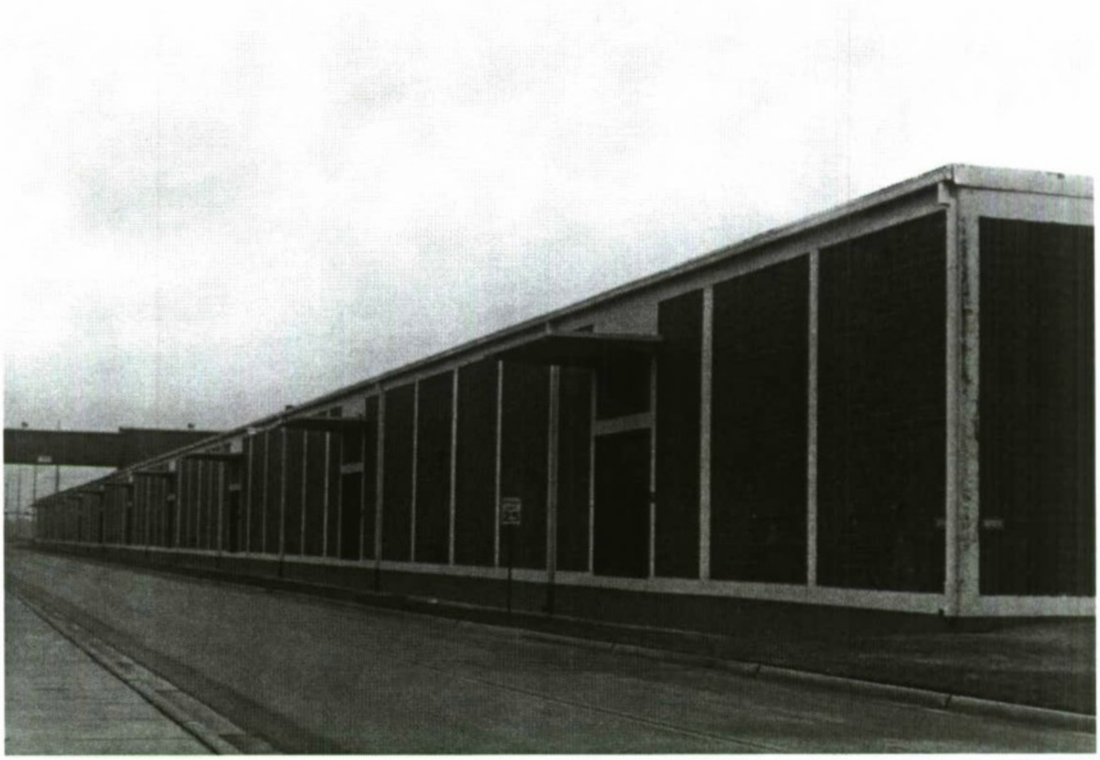

Plate 176: L.P. Kooken. Special AMC Warehouse (Building 3705), Tinker Air Force Base, 1953-1955. Photograph of October 2000. K.J. Weitze for EDAW, Inc.

Plate 177: L.P. Kooken. Special AMC Warehouse (Building 412), Tinker Air Force Base, during construction, 1955. Photograph of 1955. Kramer Collection, History Office, Tinker Air Force Base.

to its earlier completion, then move occupants and missions to their permanent post. Both the 25th Air Division (Defense) (in the Seattle area) and the 26th (initially on Long Island) reused Fighter Control Centers from World War II and had operational capabilities before the new Cold War infrastructure was even available. The 26th Air Division (Defense) stayed in its Fighter Control Center at Roslyn until 1952, then changing locations to a permanent ADCC erected at Stewart Air Force Base in New York. The 25th Air Division (Defense) also moved physical sites, from Paine Field to McChord Air Force Base south of Seattle at the outset of 1951. Activation followed for ADCCs across the country during 1951-1952. The 33rd Air Division (Defense) in Area D at Tinker was among the 11 ADCCs operational by early 1952 (see Volume I, Part IV).

The 33rd Air Division (Defense), collocated with the 546th AC&W Group in Area D, managed a shifting air defense sector as its facilities came on line. In July 1951, from temporary quarters on Tinker proper, the 33rd Air Division (Defense) controlled one of the two largest geographic air defense areas in the continental United States, within the Central Air Defense Force. At the close of 1953, the 746th AC&W Squadron replaced the 546th AC&W Group at Area D, but sustained a continuous air defense radar mission. Other AC&W radar squadrons stationed within the larger 33rd Air Division (Defense) region also reported to the ADCC at Tinker by 1953. With completion of the second group of ADCCs in the middle 1950s, taking the total ADC command posts from 11 to 16, the geographic jurisdiction of the 33rd Air Division (Defense) contracted—ceding a portion of its air defense sector to the 20th Air Division (Defense) operating at Grandview (the future Richards-Gebaur) Air Force Base in Kansas City. During the period also, the ADCC at Tinker underwent improvements in the configuration of its war room similar to such changes across ADC. As the entire air defense system shifted from ADCCs and ADDCs to SAGE during the late 1950s and early 1960s, the facilities in Area D geared up for an altered mission. The 33rd Air Division (Defense) became the 33rd Air Division (SAGE) and relocated from Tinker to Richards-Gebaur (moving physically from the ADCC in Oklahoma City to one in Kansas City). Simultaneously, ADC assigned the former ADCC at Tinker responsibility for the 32nd Air Division (SAGE). In 1960, the air defense command post picture was highly fluid. SAGE Combat Centers and Direction Centers replaced ADCCs and ADDCs—the former with sophisticated duplex computers not available before this point. ADC designated only three SAGE Combat Centers, filling in the void across the country through a selected reuse of a few ADCCs as manual (without the duplexed computers) SAGE Direction Centers. Tinker's ADCC was one of the command posts that functioned as a manual SAGE Direction Center (see Volume I, Part IV).

The air defense mission of the Area D facilities at Tinker became even more complex due to the reconfigurations of the air defense sectors during 1960-1962, as coupled with the selected delays in the activation of SAGE. The imposition of NORAD sectors overlaying the air defense geography of ADC made matters intricate. NORAD, with its headquarters command post at Ent Air Force Base in Colorado (and below ground in Cheyenne Mountain as of late 1965), set up regional command posts—NORAD Control Centers (NCCs). The NCCs reused available Type 2 and 4 Operations Buildings (that is, former ADDCs and ADCCs). NORAD, the Department of Defense, and ADC all focused on developing a web of NCCs to backup SAGE during 1961, suggesting differing figures for reuse of the 85 available Type 2 Operations Buildings at AC&W radar sites. In November 1960, ADC assigned the command post for the 32nd Air Division (SAGE) to Tinker. Set up in the Type 4 Operations Building of 1950 (Building 4020, the former ADCC), the SAGE command post awaited the takeover of its responsibilities for the 32nd Air Defense Sector from the former ADCC at Dobbins Air Force Base in Georgia. The Dobbins ADCC had previously managed the 32nd Air Division (Defense) (which had originated as an air defense sector in New England and shifted to the Southeast). Both Dobbins and Tinker command post assignments at the outset of the 1960s were temporary, pending the transfer of air defense responsibility for the region to the Montgomery, Alabama, SAGE Direction Center at Gunter Air Force Base. During the early 1960s, the Gunter

command post was preoccupied with training missions tied to Bomarc (and its testing at Eglin). In practical terms, the outcome of these changes was an air defense sector that ADC reconfigured from one in the Southwest (the former 33rd Air Division [Defense] of 1950-1959), to one that sprawled all across the Gulf Coast from Georgia to New Mexico. The 32nd Air Division (SAGE) moved its formal command post from Dobbins to Tinker, after upgrading the former ADCC in Area D, in August 1961.

More circumstances exacerbated the functioning and missions of the facilities in Tinker's Area D. The NCC at Tinker (Building 4012) also formally housed the command post for the 32nd Continental Air Defense Command (CONAD) Region—confusing indeed, as NORAD and CONAD attempted to sustain separate jurisdictional responsibilities. Like NORAD, CONAD was a joint air defense command of the Air Force, Army, and Navy. In 1957, NORAD extended its air defense responsibility to include Alaska and Canada, while CONAD—created in 1954—managed an all-military air defense of the continental United States. At Tinker, in October 1962, the 32nd Air Division (SAGE) in Building 4020 reported up the chain of air defense command to the 32nd CONAD Region headquarters—across a walkway in Building 4012. NORAD and CONAD overlapped in responsibility, with ADC reporting to CONAD. While SAGE came on line, ADC built out BUIC (see an extended discussion in Volume I, Part IV), which evolved quickly during the 1962-1970 period through I, II, and III versions. The Type 2 Operations Building in Area D at Tinker shifted from its mission as an NCC through NORAD, to a BUIC I command post. For BUIC I, ADC added a fallout protection wall and partial radiation shielding to the Type 2 Operations Building—creating a double-walled structure with a walkable passage between the inner and outer buildings. The BUIC I mission, however, was short, and the Tinker location did not continue as either a BUIC II or BUIC III site after 1965. As the automated SAGE Direction Centers became fully operational in 1963, the 32nd Air Division (SAGE), located in Building 4020, downgraded to a command post for the Oklahoma City Air Defense Sector—reporting not to the SAGE Direction Center of the 32nd Air Division at Gunter, but instead to the 29th Air Division then functional at Richards-Gebaur. (Again, air defense jurisdictional numbering was not steady over time.) Air defense responsibilities for Tinker's Area D compound fell off sharply in 1966, with its two command posts and their supporting buildings placed in the caretaker status of yet another Air Division, that of the 31st.

Each of the fast and complicated changes of 1960-1962 placed the Area D facilities in a unique position during the Cuban missile crisis of October 1962. In response to growing fears about the leadership of Fidel Castro, the Eisenhower administration had initiated planning toward a better air defense of Florida in early 1961. Known as Southern Tip, the air defense plan included a key role for the ADC command post for the region—first the former ADCC at Dobbins and then, after its relocation, the ADCC at Tinker. During 1962, the air defense hierarchy for the 32nd Air Division (SAGE) and the 32nd CONAD Region—as well as the two air defense networks' relationship to one another—all funneled to the Type 2 (Building 4012) and Type 4 (Building 4029) Operations Buildings in Tinker's Area D. Although ADC had intended to move the command post responsibility from Tinker to the SAGE Direction Center at Gunter by October 1962, this action was still delayed and the post remained in Oklahoma City during the Cuban missile episode. During the October crisis, and for the immediate few months following, the 32nd CONAD Region headquarters housed in Building 4012 served as the top air defense command post for its Georgia-to-New Mexico jurisdiction. Activities and directions to all lower levels within the region, and particularly in Florida during the crisis, derived from this command post (with the next tier of responsibility, Headquarters NORAD at Ent). Actual duties included the management of air defense for the region—as the standard ADC mission—and the prevention of Soviet aircraft access to Cuba. The expanded role of the 32nd CONAD Region to stop planes carrying missiles, bombs, rockets, warheads, or related electronic equipment was outside the previous "normal" air defense mission, but did not include any strategic planning for invasion or insertion, Air Force roles undertaken by SAC and TAC.

The air defense tenant mission at Tinker was long and steady, with changes over time and sharp punctuations in its importance. Tinker's role during October 1962 was a key one in American military air defense—yet ironically, if the Cuban missile crisis had occurred before August 1961 or after August 1963, air defense management for the Southeast would have occurred from command posts at Dobbins in Georgia (in the ADCC) or at Gunter in Alabama (SAGE). The dramatic happenstance of responsibilities for the command post at Tinker during the crisis illustrated not only the extreme speed of adaptation from one air defense command network and its technologies to another at this juncture in the Cold War, but also the value of layers of redundancy for both mission—and infrastructure suited to mission. In 1970, Tinker's Area D assumed an air defense communications and intelligence tasking for GEEIA. GEEIA, as a subcommand of AFLC, had existed at Tinker by the late 1950s, taking over the Area D compound to accommodate spatial and security needs. GEEIA evolved into the SCA subsumed under AFCC, and later into the Engineering Installation Center and the Engineering Installation Division / Group (extant today) (see Volume I, Part IV).

Early in the Cold War, ADC had also considered placing an alert FIS at Tinker, a typical complement to the placement of an ADCC at an installation. As a preliminary step in 1951, TAC activated the 185th Fighter Wing at Will Rogers Field, 13 miles west of Tinker.[30] In autumn 1952, a discussion of "Air Defense Command fighter interceptor items" was part of the master planning process at Tinker. The Oklahoma City AMA and Headquarters ADC worked together on the physical location of an alert hangar and apron on the Tinker flightline, as well as the sites of a readiness hangar and other ancillaries. The Air Force had allocated funding for ADC fighter-interceptor alert facilities at Tinker in FY 1953. Initial intent placed the alert area at the south end of the north / south runway, but by late 1952 representatives of ADC and Headquarters Central Air Defense Force decided to seek a site southwest of the north end of the northwest / southeast runway. The final choice for fighter alert facilities required the purchase of additional land, although the Air Force had already allowed sufficient monies for such an acquisition. The northwest / southeast runway was Tinker's non-instrument runway in 1952, 150 feet wide by 7,842 feet long, another complicating factor, as no plans existed to either widen or lengthen the runway. Air Materiel Command relinquished the original locational choice for the ADC alert area at the south end of the north / south runway to another anticipated Air Force tenant of the early 1950s, MATS.[31] The decision to site ADC's fighter alert apron and hangar off the instrument runway ultimately precluded constructing the facility. Soon fighter-interceptor aircraft were no long propeller pursuit planes, but rather jets requiring 9,000-foot runways. The land issue also turned out to be a major one. To construct the 45-degree alert taxiway and apron required crossing Depot Road, and hence its realignment. Instead, the Air Force chose to develop the area as officer and family housing—a use first contemplated when ADC planned its alert apron off the north / south runway (with housing in that scenario moved further west). In late 1954, Tinker lengthened its north / south instrument runway through a 4,500-foot extension,[32] creating a runway 12,100 feet long by 200 feet wide by November 1955 (Plate 178). Engineers designed the runway explicitly for the B-47, although the infrastructure was B-52 capable. The World War II reinforced concrete runway functioned as the sub-base, with an upper surface of asphaltic concrete. Workers built 1,000-foot reinforced concrete overruns to accommodate landing modern jet bombers at each end of the runway.[33] While the north / south runway was under improvement, the northwest / southeast runway was the only runway functional at Tinker, with Air Materiel Command next upgrading its paving during 1955-1956.[34]

While ADC never established a FIS at Tinker, one final important air defense mission arrived at the installation in July 1976: the 552nd AWAC Wing. While ADC had revised its BUIC I, II, and III command post networks during the 1960s, taking SAGE progressively off line, both ADC and NORAD had also looked at the idea of a "mobile NCC." The first studies, undertaken through the Electronic Systems Division (ESD) at Hanscom Air Force Base in Massachusetts during the early

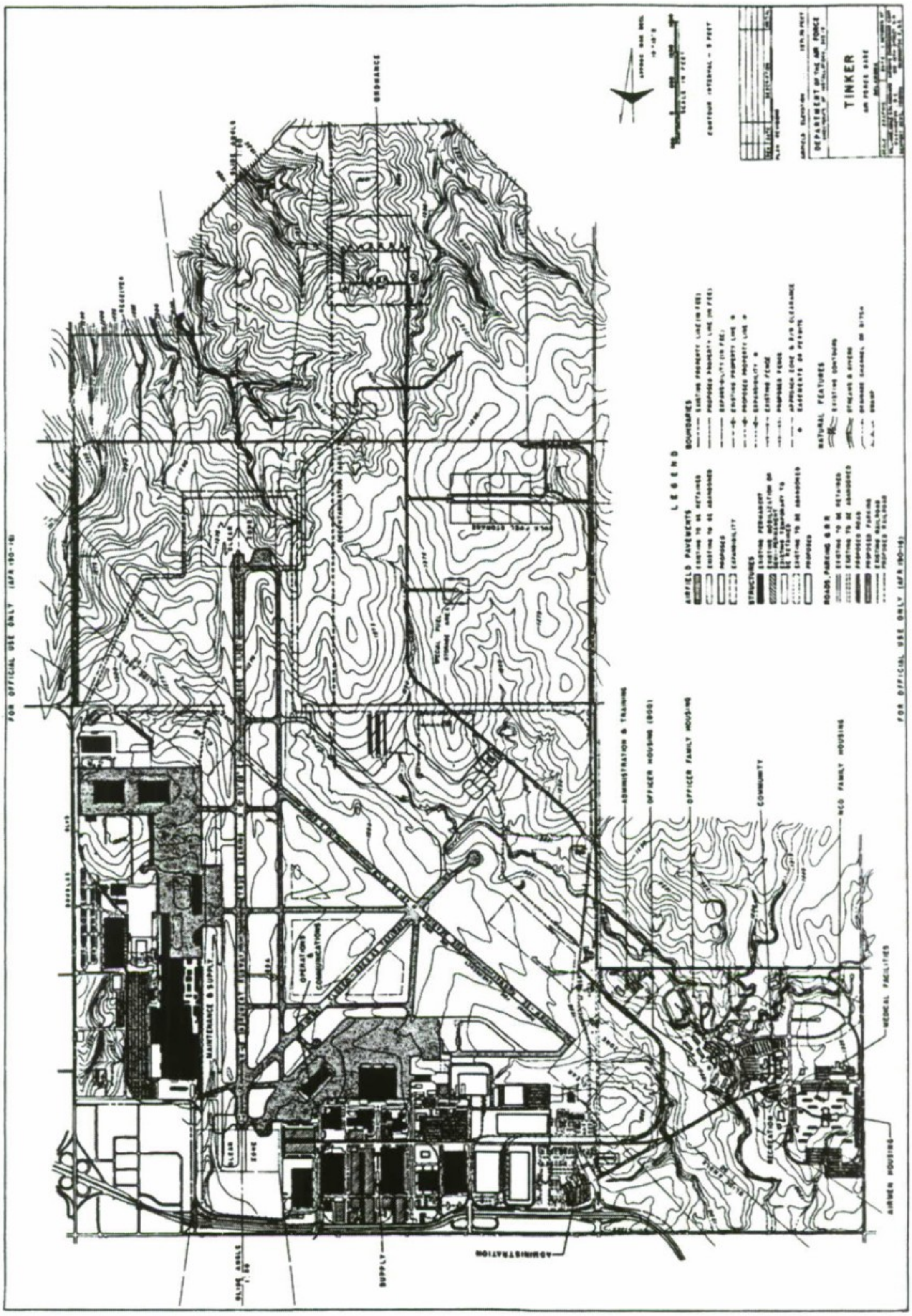

Plate 178: Directorate of Installations, Headquarters United States Air Force. Master Plan for Tinker Air Force Base, October 1957. North / south runway incorrectly printed as 11,200 feet. Collection of K.J. Weitze.

1960s, proposed moving the air defense computer equipment randomly among three NCCs—conceptually similar to programs suggested to hide Minuteman intercontinental ballistic missiles (ICBMs). ADC declined the idea, but did move toward an "airborne BUIC." The command analyzed its Airborne Early Warning and Control (AEW&C) radar surveillance wings established in the middle 1950s, and devised the Airborne Surveillance and Control System (ASACS) in late 1962. By the middle 1970s, "airborne BUIC" had become AWACS. The 552nd AWAC Wing at Tinker had formerly been stationed at McClellan in California. The air defense mission had also shifted predominantly from ADC (which had become Aerospace Defense Command as of 1967) to TAC as of the late 1960s. The TAC tenant mission of the 552nd AWAC Wing at Tinker reused the World War II Airplane Repair Building (Building 230) for its major maintenance hangar,[35] with E-3A aircraft parked in a semicircular arrangement of three planes immediately northeast of Building 240 (the Operations – Transport Squadron and Flight Test Hangar).

The E-3A, a modified Boeing 707-320B commercial aircraft, featured overland lookdown radar in a 30-foot diameter rotating radome capable of seeing more than 200 miles. The surveillance aircraft replaced the EC-121 used for the AEW&C wings at Otis Air Force Base on Cape Cod, in Massachusetts, and at McClellan. Other electronic equipment included advance surveillance radar, navigation and guidance systems, communications, and a command and control computer. During the initial months of operation, the 552nd AWAC Wing trained for its air defense mission using EC-130 aircraft that were modified through the addition of Airborne Battlefield Command and Control Center (ABCCC) capsules.[36] The 7th ACCS, stationed at Keesler Air Force Base in Mississippi, deployed to Tinker for the readiness assignment. The 7th ACCS reported to the 552nd AWAC Wing at Tinker.[37] Modified from C-130 troop carrier aircraft during the 1960s, seven EC-130 propeller-driven planes carried the ABCCC, a 40-foot long, 20,000-pound capsule fitting into the aircraft cargo bay on a mounted rail system. The EC-130 ABCCC worked in tandem with the E-3A, accepting real-time data links from the surveillance aircraft.[38]

The 552nd AWAC Wing received its first E-3A in late March 1977.

> In a tactical role, the E-3A was to provide quick reaction surveillance, command, control and communications necessary to effectively manage fighter forces and support forces in such air operations as air defense, counter air, interdiction, close air support, rescue, reconnaissance and airlift. ...The E-3A could detect and track enemy forces operating at low altitudes over any type of terrain and identify and control friendly aircraft in that same area or adjacent areas. Having a quick deployment capability, the AWACS [Airborne Warning and Control System] enhanced the ability of tactical air forces to deploy to potential trouble spots around the world.
>
> Information gathered by the E-3A would be downlinked to major command and control centers via the Joint Tactical Information Distribution System (JTIDS), a secure, jam resistant, high volume communications system. Through this capability, the volume of real time data made available would improve the centralized timely management of national assets.

TAC's commander, General Robert J. Dixon, emphasized that the E-3A allowed the Air Force to "think, reason and act, rather than just react." AWACS tied together air defense and let the American military "get the most out of everything else we have."[39]

The airborne command post mission at Tinker included hosting alert aircraft and accomplishing the basic depot functions for a variety of airborne command post planes. As the 552nd AWAC Wing set up at the installation, wing personnel occupied multiple buildings on base before workmen finished construction for a permanent command post in January 1977.[40] The air defense operation was sizable, utilizing parts of Buildings 201, 202 224, 228, 230, 283 and 284.[41] Tinker added Building 283, an AWAC simulator, in 1976.[42] The 552nd AWAC Wing at Tinker participated in both TAC Red Flag and Blue Flag exercises in 1978—at Nellis Air Force Base in Nevada and at Eglin, respectively (see Volume II, Chapter 4). These war games, six Red Flags and four Blue Flags during 1978, were major preparedness exercises that substituted mock situations for unknown battle scenarios of the future and thus helped to guarantee the successful survival of TAC fighter operations when actual conditions arose. In April 1978, TAC named the E-3A, the *Sentry*. The same month, Detachment 2 of the 552nd AWAC Wing deployed to Keflavik Naval Air Station, adjacent to Keflavik Air Base, in Iceland. Two E-3As made up the detachment to Keflavik, assuming an alert posture there in October. The E-3As replaced EC-121s stationed at the Naval base, with Tinker aircraft and crews rotating home to Oklahoma every 33 days. The intertwining of an Air Force and Navy airborne command post mission at Keflavik also foreshadowed events at Tinker in the late 1980s. During 1978, TAC assigned the 552nd AWAC Wing responsibility for all of its airborne command and control aircraft, including the E-3A, EC-130 ABCCC, and EC-135. Reporting squadrons were stationed at locations distinct from Tinker.[43]

The Oklahoma City AMA (the Oklahoma City Air Logistics Center [ALC] as of 1974) additionally served as the program manager for the Airborne Command Post System during the Cold War. This mission complemented the presence of TAC's 522nd AWAC Wing at the base. Tinker had maintained and overhauled the basic KC-135 since July 1956, receiving that mission simultaneously with a parallel assignment for the B-52. By 1960, the Oklahoma City AMA had modified five KC-135s for SAC as Looking Glass airborne command posts. In February 1968, AFLC assigned the EC-135 maintenance and modification workload to Tinker, and in early 1975 the command placed the repair mission for AWACS at the base in anticipation of the alert mission that would arrive in 1976. Accumulation of depot taskings for the airborne command post continued in 1979 with the addition of logistics support for the North Atlantic Treaty Organization (NATO) E-3A aircraft, as well as supply and maintenance responsibility for the E-4B Presidential Airborne Command Post.[44] The largest airborne command post fleet was that of the E-3A, with 68 worldwide in 1992. Developed over more than a 10-year period before deployment in 1977 and a mainstay of the second half of the Cold War, the E-3A provided airborne surveillance and command posts for the United States (34 aircraft, delivered 1977-1984); NATO (18 aircraft, delivered 1982-1985); Saudi Arabia (five aircraft, delivered 1986-1987); Britain (seven aircraft, delivered 1991-1992); and, France (four aircraft, delivered 1991-1992). In 2000, the fleet of E-3As is 67, after the loss of one United States Air Force E-3A in 1995.[45]

Toward the end of the Cold War, the Department of Defense unified the ACCS and AWAC missions at Tinker, placing alert airborne command and the maintenance of airborne command and surveillance aircraft at a single installation. In late 1982, the 7th ACCS no longer sustained the EC-130 ABCCC mission. In September that year, the 3rd ACCS activated at Tinker.[46] Earlier that year Hudgins, Thompson, Ball & Associates, the architectural-engineering firm handling many major commissions for Tinker since 1951, designed an alert crew building for the 3rd ACCS (Building 989). The Air Force transferred EC-130s from Keesler to Tinker, situating the command post aircraft at the southern end of the northwest / southeast runway and providing taxiway access to the main north / south runway.[47] A separate rectangular apron accompanied the alert area. In 1986, Tinker expanded the alert area through the addition of a new E-3A maintenance hangar immediately adjacent to the alert crew quarters[48] (Plate 179). By the late 1980s, the missions of the E-3A surveillance aircraft and EC-130 command post were coalescing in a distinct combined alert area, with major components of

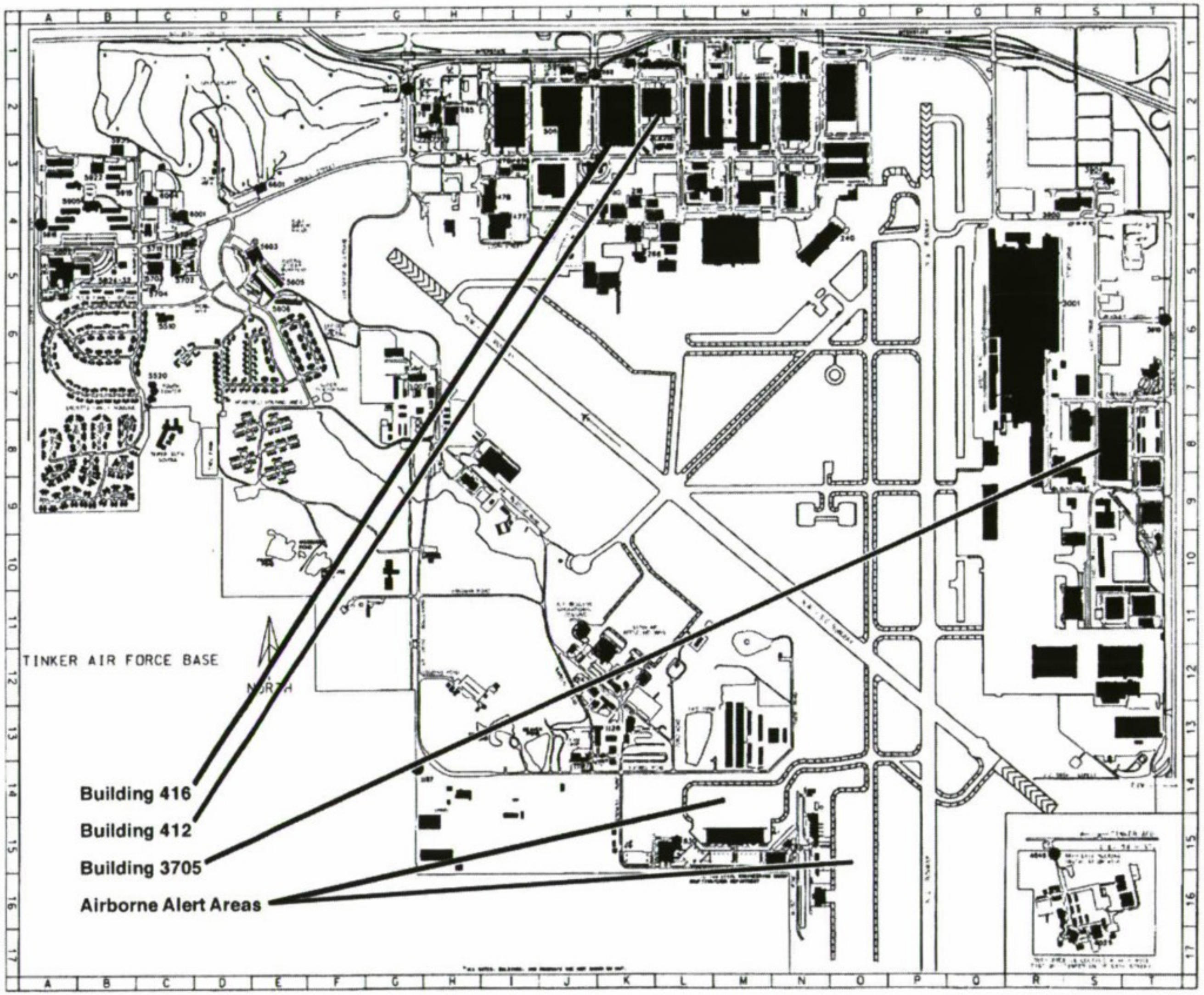

Plate 179: Master Plan, Tinker Air Force Base, 2000. Annotations added. Upper middle: Hudgins, Thompson, Ball & Associates Warehouse (Building 416) and L.P. Kooken, Special AMC Warehouse (Building 412). Right: L.P. Kooken, Special AMC Warehouse (Building 3705). Lower middle: Airborne Alert Areas, 552nd AWAC Wing (E-3As) and Navy E-6As. Lower right: inset plan for Area D. Courtesy of Civil Engineering, Tinker Air Force Base.

the AWAC wing remaining in its original location at Buildings 230 / 240. The operational airborne command post mission at Tinker next added the E-6A, also an aircraft modified from the Boeing 707, during 1989-1992. The E-6A replaced the EC-130 and in 2000 was a Navy mission. Boeing built 16 E-6As for the Navy.[49] An alert configuration of the aircraft was sited next to the E-3A area at the southern end of the northwest / southeast runway (see Plate 179). In autumn 1989, construction of a very large E-6A maintenance hangar, along with ancillary Navy facilities for the E-6A mission, was underway.[50] At the Cold War's end, the Navy E-6A and Air Force E-3A missions featured alert aprons at Tinker in close proximity (see Plate 179), in addition to the World War II hangars (Buildings 230 and 240) adapted for AWACS and its permanent command post of the late 1970s.

By middle 1950s, the Oklahoma City AMA had received its first aircraft and jet engine maintenance and modification projects, and was well along in establishing itself as a major base for a sustained air defense tenant mission. New construction for warehouses and a four-cell jet engine test structure (Building 3703) designed by the major Chicago firm of Graham, Anderson, Probst & White,[51] coupled with the extension of the primary runway to over 12,000 feet, supported the overhaul for a changing program of aircraft and engine work and included a steady sequence of jet engine production line efforts. Immediately before mid-decade, Air Materiel Command assigned Tinker modification of the B-47 for reconnaissance (the RB-47). More B-47 work followed through phaseout of the bomber in the middle 1960s. In 1954, the base began stockpiling parts for the B-52 in support of SAC's first wing of the bomber. In 1956, the Oklahoma City AMA became the major depot for both the B-52 and KC-135 (and the family of C-135 aircraft). In this year too, Air Materiel Command tasked Tinker with its first guided missiles. Like the missions of aircraft and engine modification, assignments for the overhaul, maintenance, and upgrading of missiles required certain facilities and capabilities at the individual depots across the command and tended to be delegated on a sustained weapons system basis at particular installations (policy in mid-1957).[52]

Very often, Air Materiel Command designated a depot as the primary program manager for an aircraft or missile in advance of the weapons system's availability. Sometimes in these instances the command would change an early assignment from one installation to another—such as the shift of primary tasking for the maintenance and modification of the B-36 from Tinker to Kelly over the 1947-1951 period. (McClellan was another Air Materiel Command depot that received a B-36 mission for a short period during 1953-1954. For most of the Cold War, however, the base sustained fighter aircraft workloads.) In other instances, the primary tasking was so large and long-lived, as for the B-52 of the middle 1950s through the end of the conflict and beyond, that more than one depot served as a primary location for overhaul of the aircraft. Tinker became the lead B-52 depot installation for Air Materiel Command in 1956, with assignment of executive management of all models of the bomber in 1958. Over the next few years, the command added the sequentially more advanced models of the B-52 to Tinker's workload. Nearly simultaneously, Air Materiel Command advanced the bomber workload of the San Antonio AMA at Kelly from the B-36 to the B-52 in 1956. (Kelly also received a B-47 depot mission paralleling work on the aircraft at Tinker.) Both bases, then, were important for the B-47 and B-52 mission. Both also kept a major B-52 mission through the whole of the Cold War. In the case of Tinker, the depot workload for the B-47 and B-52, as well as for the families of the KC-135 and EC-3 aircraft, additionally tied the installation very strongly to a single aircraft manufacturer—Boeing (a situation that reflected official command policy during the first half of the 1950s).

Air Materiel Command tasked Tinker with its first missiles assignment in November 1956, designating the depot as the lead for the experimental Bomarc interceptor missile.[53] The Bomarc mission at Tinker, however, was very short, actually only a paper assignment before an almost immediate shift to the Ogden AMA at Hill Air Force Base in Utah (see Volume II, Chapter 6). The reverse situation occurred for the Quail (GAM-72)—first assigned to Hill and then moved to Tinker.

For the Bomarc, an air defense weapons system, a tasking at the Oklahoma City AMA was due to the missile's manufacture by Boeing.[54] Most depot designations for missiles were still preliminary when Air Materiel Command reorganized its method of assigning missions from one focused on the manufacturers to one concentrated on interrelated weapons systems, in June 1957. The command allocated missiles overhaul and modification by type, with long-range ballistic missiles assigned to the San Bernardino AMA at Norton, guided air rockets (GARs) to the Middletown AMA at Olmsted Air Force Base in Pennsylvania, tactical missiles (TMs) to the Warner Robins AMA at Robins, interceptor missiles (IMs) to the Ogden AMA at Hill, and GAMs to Tinker—the latter including the Rascal (GAM-63), Quail (GAM-72), Hound Dog (GAM-77), and Skybolt (GAM-87). Assignment of the Rascal (GAM-63) to Tinker in October 1957 (as with the Bomarc) was brief.[55] The Rascal, a missile in development since 1946 and in flight test in 1953, featured a nuclear warhead (as well as early plans for a chemical warhead using sarin gas [GB]).[56] Intended as a weapons system for SAC, the Rascal had a range of 100 miles. Airmen guided the missile to its final target from its director aircraft, the B-47. As the overhaul depot for the B-47, Tinker was the appropriate location for maintenance and modification of the Rascal. In late 1958, however, the Air Force cancelled the Rascal, immediately before deployment of the first operational SAC B-47 wing armed with the missile.[57] The GAM-63, then, had been the second missiles paper assignment for the Oklahoma City AMA.

The GAM mission that solidified at Tinker was the Hound Dog and Quail pair. Air Materiel Command tasked the Oklahoma City AMA with the Hound Dog (GAM-77) in July 1957 and the Quail (GAM-72), its decoy companion missile, in June 1961. Both were missiles launched from the B-52. Air Materiel Command was able to consolidate the missions of modifying the B-52 to carry the Hound Dog and Quail (as of February 1960), and program systems management for the missiles. Modification and maintenance of the Hound Dog was underway at the Oklahoma City AMA in August 1961, with full executive management for the Quail a year later[58] (Plates 180-181). Briefly at the outset of the 1960s, Air Materiel Command had also considered giving each AMA the responsibility for construction management of its regional ICBM launch sites. Loss of this potentially large weapons systems support mission during FY 1961 to the primary AMA for ICBMs at Norton (the San Bernardino AMA)—coupled with the very temporary assignment of the Bomarc and cancellation of the Rascal, made the Hound Dog – Quail mission especially important to the base. The reliability and accuracy problems of the Hound Dog, and its need for an extended modification program to integrate the missile with its launch platform the B-52, reinforced the interrelated nature of the overall weapons system. The manufacturer of the Hound Dog, North American Aviation in Los Angeles, worked closely with Tinker personnel. The Hound Dog, like the Rascal before it, featured a nuclear warhead and was the first true cruise missile of the Air Force. SAC deployed the Hound Dog – Quail weapons system for a portion of its alert bombers during the early 1960s. Of the 65 SAC alert squadrons in the continental United States, Canada, and Puerto Rico, 14 received the Hound Dog – Quail pair, with another 15 on alert with the Hound Dog alone. The Quail stood full alert in July 1962; the Hound Dog, in March 1963. Air Force personnel tested the Hound Dog – Quail for SAC during 1960-1962 at Eglin in Florida and at the White Sands Missile Range in New Mexico.[59] Eglin also hosted the first SAC alert squadron operational with the weapons system. Tinker directly supported these tests.[60] MATS, using C-124 transport aircraft, delivered the missiles to Oklahoma City, while the Middletown AMA at Olmsted stored about one-third of the Hound Dog and Quail systems components.[61] AFLC modified more than 1,300 Hound Dog and Quail missiles at Tinker for the program.[62] The installation sustained the Hound Dog – Quail mission through the pair's demilitarization in 1978, reclaiming parts and materials from 603 missiles.[63]

Acquiring the Hound Dog – Quail mission at the Oklahoma City AMA necessitated the modification of existing buildings and the strong backing of SAC. To accommodate the Hound Dog, Tinker

Plate 180: Hound Dog (GAM-77) Production Line Overhaul in Building 230, Tinker Air Force Base, 1961-1962. In *History of the Oklahoma City Air Materiel Area 1 July 1961 – 30 June 1962.*

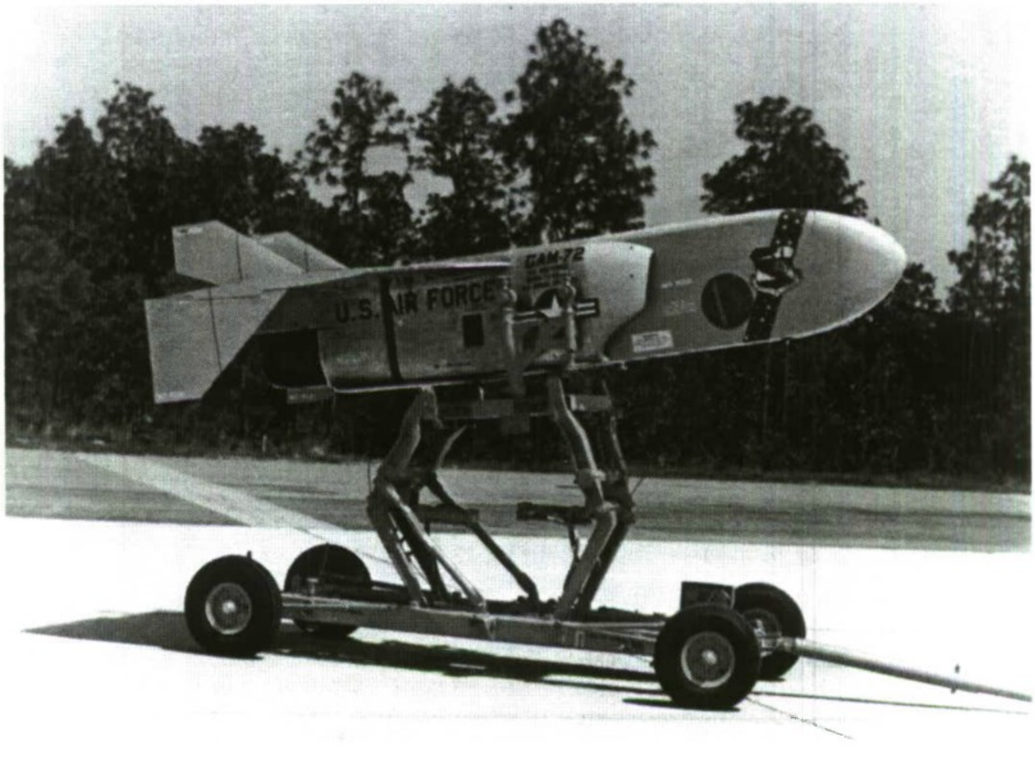

Plate 181: Quail Decoy (GAM-72), Tinker Air Force Base, 1962. In *History of the Oklahoma City Air Materiel Area 1 July 1961 – 30 June 1962.*

altered parts of Buildings 230 and 214 in spring 1961.[64] Building 230, the four-bay Airplane Repair Building of World War II (see Plate 173), had earlier supported the B-36 mission and would convert for AWACS maintenance in the later 1970s. Successful adaptation of Building 230 paralleled interior additions SAC frequently made to the double-cantilever hangars of the early 1950s (see Volume I, Part IV) for a combined Hound Dog – Quail assembly, guidance, and maintenance shop. When found in the double-cantilever hangar, the Hound Dog – Quail shop occupied about 40 percent of the structure. Typically, SAC also augmented the hangars with missile triangulation stations—brass plates set in reinforced concrete piers independent of the hangar floor. Modifications for Building 214, the eight-cell engine test facility designed by J. Gordon Turnbull in early 1942, focused on the conversion of Test Cell 5 for the Hound Dog (Plate 182).[65] The adaptation of Buildings 201, 204 and 205 was also critical for Tinker's Hound Dog – Quail mission. Erected during World War II (see Plate 173), the small cluster of structures included Building 204. Used for repair of the Norden bombsight, Building 204 had sustained an electronic calibration mission from the first. (The Norden analog computer assisted in target accuracy.) Buildings 201 and 205 were also originally designed as equipment repair shops. In mid-1953, the Oklahoma City AMA integrated Buildings 201, 204, and 205 as a single complex, adding an annex to accommodate more armament and electronics tasks (Plate 183). At the close of 1955, Air Materiel Command further adapted Building 201 as a radar sighting station.[66] Preparations toward a missiles mission in Building 205 date to at least June 1956, when Tinker added a collimator pit (possibly in anticipation of the Bomarc mission). Collimators calibrated missiles, and were often incorporated into launch complexes.[67] Major remodeling of the Building 201-205 complex for the Hound Dog included the addition of an 8,400 square-foot clean room in 1963 for the repair and overhaul of the guidance and flight control systems of the missile. During the next year, Tinker added another 18,400 square-foot clean room for overhaul of the Hound Dog's inertial guidance. In 1966, personnel modified Building 205 for yet more clean rooms, taking the total specialty space to over 38,000 square feet.[68]

SAC supported the integrated Hound Dog – Quail and B-52 missions at the Oklahoma City AMA. The command recommended to AFLC that the sequential modifications of the Quail (as GAM-72, GAM-72A, and GAM-72B) take place in a "factory-type overhaul program" rather than on site at its installations. Work on the Quail, a McDonnell Aircraft Corporation project, also integrated efforts between the manufacturer and the depot. Tinker sent personnel "to school" at McDonnell "to learn how to modify the missile."[69] SAC was so pleased with the work at Tinker that the command requested its next anticipated guided missile, the Skybolt (GAM-87), be placed with the Oklahoma City AMA as well. The Vice Chief of Staff for SAC stated in 1961:

> The materiel support by a single AMA of the Hound Dog and the Quail has been proven a sound concept. The electronic tie-in between the Skybolt and the B-52 is even more complex than the Hound Dog / B-52 combination and will require the closest coordination.

At this juncture, AFLC was again considering separating aircraft overhaul programs from those of associated missiles, and was intending to place the Skybolt at the Ogden AMA. The Air Force cancelled the Skybolt program in 1962 (see Volume II, Chapter 6).[70]

From 1966 through the close of the Cold War, AFLC continued to assign Tinker a missiles mission, including the SRAM (AGM-69) in December 1966, the subsonic cruise armed decoy (SCAD) (AGM-86A) in March 1969 (terminated in engineering development during July 1973), the ALCM (AGM-86B) in October 1974, and the GLCM (BGM-109) in February 1977.[71] The SRAM and the ALCM were both cruise missiles with nuclear warheads, launched from the B-52 and F-111. The

Plate 182: J. Gordon Turnbull. Engine Test Cell Facility (Building 214), Tinker Air Force Base, 1941-1942. Undated photograph. Kramer Collection, History Office, Tinker Air Force Base.

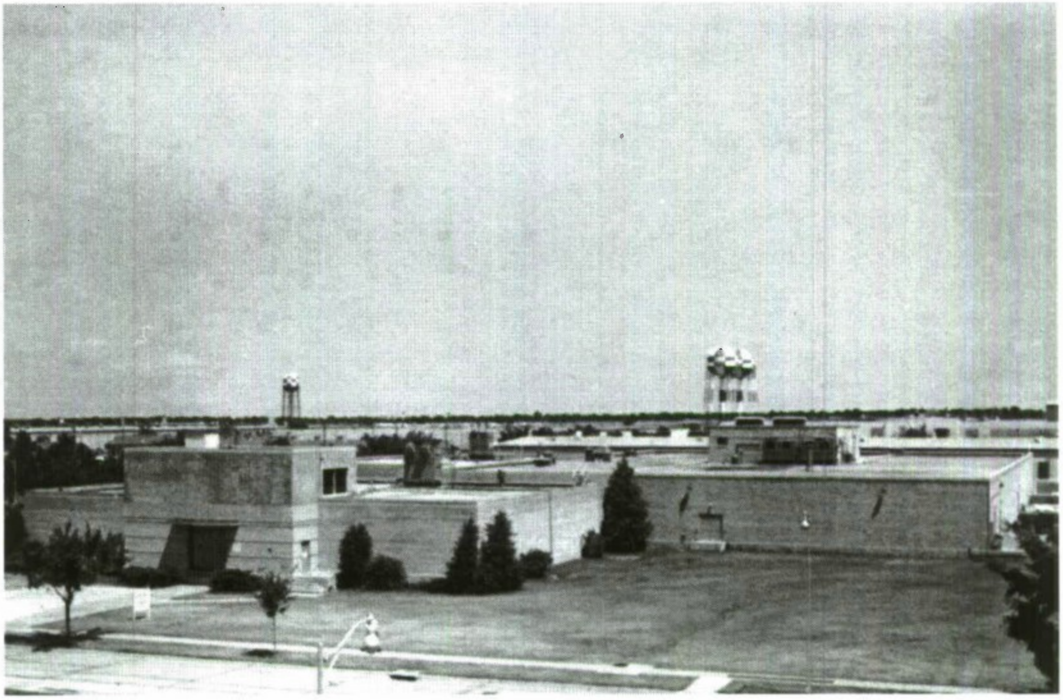

Plate 183: Buildings 201, 204, and 205 combined as a single complex for armament and electronics testing, Tinker Air Force Base, 1953-1955. Photograph of ca.1960-1962. Courtesy of the History Office, Tinker Air Force Base.

Oklahoma City ALC (the follow-on to the Oklahoma City AMA) modified B-52s for the SRAM over a four-year period ending in October 1976. As had been the case for the Hound Dog – Quail and B-52 integrated mission at Tinker, that for the SRAM – B-52 was of very high importance to SAC. Personnel at the Oklahoma City ALC modified 272 B-52G / H aircraft for the SRAM (15 SAC wings).[72] At this time, SAC was also in the midst of its dispersal and satellite basing program, expanding its alert areas of the late 1950s at certain locations and adding bare-bones satellite alert aprons and support structures at others. The B-52 – SRAM was the weapons system for this SAC mission. SAC had planned for a satellite alert at Tinker early, in 1967, apparently removing the installation from consideration after 1971 before the program was in buildout (see Volume I, Part IV). Under President Ronald Reagan in the last years of the Cold War, a similar pairing of the B-52 – ALCM necessitated a final modifications project at Tinker. SAC again expanded and renovated selected of its late 1950s alert facilities for the ALCM.[73] For both the SRAM and ALCM missions, the role of the Oklahoma City ALC focused on the modifications required for mating the cruise missiles to the B-52. AFLC assigned repair and overhaul of the SRAM and ALCM to the Ogden ALC at Hill—a change from the command's handling of the Hound Dog / Quail (see Volume II, Chapter 6). The final missile tasked to Tinker, the GLCM, was a critical weapons system deployed at overseas air bases in mobile blast-resistant shelters. The Intermediate-Range Nuclear Forces (INF) Treaty signed by President Reagan and General Secretary Mikhail Gorbachev in December 1987 called for the elimination of the GLCM,[74] a weapons system that like the rail-mobile Peacekeeper (Rail Garrison) was a bargaining chip at the conclusion of the Cold War.

Other Cold War missions at Tinker were ones for additional aircraft; support during the Vietnam War (including storage of the steel liners for Concrete Sky hardened aircraft shelters);[75] involvement with selected space missions; and, additional programs tied to nuclear weapons. The Concrete Sky test program was especially noteworthy from 1966-1973, with steel shelter liners shipped to Vietnam and supplied for individual testing through the 10 phases of the Air Research and Development Command (ARDC) / Air Force Systems Command (AFSC) program. Tinker released shelters to support Air Force Weapons Laboratory (AFWL) testing at Kirtland Air Force Base and the Sandia National Laboratories in Albuquerque (see Volume II, Chapter 8). At the end of 1971, 95 Concrete Sky 48-foot by 72-foot shelters were in storage at Tinker.[76] Tinker was also a recipient of another type of prefabricated structure developed through AFSC for the Vietnam War: the Birdair hangar. The Birdair structure featured bowed aluminum-tube arches, sheathed in a pretensioned, flexible fabric shell (see Volume II, Chapter 4). After a major fire in the former Douglas plant at Tinker in November 1984, personnel erected 10 Birdair hangars to house engine parts while cleanup crews repaired Building 3001 (see Volume II, Plate 56).[77]

Key Associated Architects and Engineers

Architects and engineers with known national presence who designed buildings and structures for Air Materiel Command / AFLC at Tinker Air Force Base during the Cold War, or who were responsible for key buildings from World War II that were adapted for major Cold War programs, included Graham, Anderson, Probst & White, and several firms discussed in Volume I and other chapters of Volume II, as noted:

- Ammann & Whitney, of New York (Volume I, Part II);
- Graham, Anderson, Probst & White, of Chicago;
- Holabird, Root & Burgee, of Chicago (Volume I, Parts III and IV);
- L.P. Kooken, of Baltimore (Volume I, Part II);
- Fred N. Severud, of New York (Volume II, Chapter 4); and,
- J. Gordon Turnbull, of Cleveland (Volume I, Part III).

Graham, Anderson, Probst & White

Graham, Anderson, Probst & White was one of the leading partnerships in Chicago during the height of that city's reputation for architectural and engineering excellence. The firm designed reinforced concrete structures for Air Materiel Command, and was responsible for the standard jet engine test cell facility built at selected depot installations during the early 1950s (following in the footsteps of J. Gordon Turnbull for the design of pre-jet engine test cells). Graham, Anderson, Probst & White had very strong links to the Army Air Corps and the Army Air Forces during World War II. While the firm had designed complete air bases in some instances (such as ones in Puerto Rico), the enduring tie to Air Materiel Command came through a commission in 1941. The Air Corps hired Graham, Anderson, Probst & White to take partially completed plans, sketches, and drawings completed by, or subcontracted through, the Quartermaster Corps for specific technical buildings needed at its depots and create finished designs. Graham, Anderson, Probst & White handled 12 technical buildings for the Air Corps Materiel Division at Wright Field—such as buildings for engine, radio, and armament test and repair.[78] Among these technical buildings were at least two, the Engine Test Cell Facility and the Armament, Fire Control, Supply, and Repair Building, that were the work of J. Gordon Turnbull (see Volume II, Chapters 6, 11, and 12). The early link between Graham, Anderson, Probst & White and J. Gordon Turnbull, and between both architectural firms and the predecessor commands to Air Materiel Command at Wright Field, suggests further research. Graham, Anderson, Probst & White continued to draft standardized drawings sets for the Air Force during the 1950s.

Graham, Anderson, Probst & White derived from the premier Chicago firm of Burnham & Root. Ernest Robert Graham (1868-1936) had begun practice as an architectural draftsman with Burnham & Root at age 20. After the death of John Wellborn Root in 1892, Graham rose to a virtual partner in Burnham & Root, directing the firm's work for the Chicago Worlds Fair (Columbian Exposition) of 1893. After the death of Daniel Burnham in 1912, Burnham & Root continued as Graham, Burnham & Company. Key members of the firm were Ernest Graham, Daniel Jr. Burnham, Hubert Burnham, Peirce Anderson, Edward Probst, and Howard J. White. In 1917, the firm's name formally changed to Graham, Anderson, Probst & White. The firm designed many important office and civic buildings, banks, and railroad stations for Chicago and the larger Midwest. Graham, Anderson, Probst & White's work in the East and West included major buildings in New York, Baltimore, Washington D.C., Philadelphia, and San Francisco. Peirce Anderson (1870-1924) served as the head of the firm's Department of Design early in the century and managed a drafting staff that sometimes numbered over 200 men. Among his specific projects were those for the Federal Reserve Banks in Detroit and Oklahoma City. Edward Probst (1870-1942) had joined Burnham & Root as a draftsman just before the turn of the century. (Marvin G. Probst, Edward's son, signed the drawings for the jet-engine test cell of 1951 at Tinker.) Howard Judson White (1870-1936), like Edward Probst, had joined Burnham's office in 1898.[79] Graham, Anderson, Probst & White incorporated after the death of the last original partner in 1942. Marvin Probst served as the first president of the incorporated partnership. After World War II, the firm designed primarily for corporate clients. In 1970, William Surman became the second president of Graham, Anderson, Probst & White. In this era, the firm was best known for precast concrete and high-rise design. In 2000, William Surman's son Robert runs Graham, Anderson, Probst & White as its third president. The firm's military work appears to have been concentrated during the 1940s and 1950s.[80]

---

[1] The reader can trace the broad patterns of lineage for Tinker Air Force Base in Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). The Tinker chapter includes the sequence of installation names through 1982; dates of establishment, construction, and occupancy; base operating units;

base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base.

[2] Architectural historians define "buildout" as a planned building program for a particular type of highly standardized structure, usually with the construction process encompassing years of time. This situation is common in the Air Force. A warehouse, command post, or hangar, for example, might be designed in 1951, but constructed nearly unmodified for half a dozen years while the structure was "built out" at multiple locations.

[3] Joseph Trnka and William Manley, *Historic Building Inventory and Evaluation of Air Force Plant 4, Fort Worth, Texas* (Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, January 1997), 3-22.

[4] Joseph Trnka and William Manley, *Historic Building Inventory and Evaluation of Air Force Plant 3, Tulsa, Oklahoma* (Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, November 1996), 3-22-3-24.

[5] Jack Reise, *Tinker Air Force Base A Pictorial History* (Tinker Air Force Base: Office of History, Oklahoma Air Logistics Center, Air Force Logistics Command, 1983), 1-9.

[6] The Austin Company, "Modification Center No. 17," 15 May 1943.

[7] Dan Schill, "The Early Years of Building 3001," draft for an article in the *Tinker Take Off*, file "Building 3001," History Office, Tinker Air Force Base, 16 July 1999. Tinker Air Force Base nominated the Douglas aircraft plant for the National Register of Historic Places in 1995. See, Charles M. Johnson, *Nomination Package for Historic District Eligible for the National Register of Historic Places for Tinker AFB Oklahoma City, Oklahoma Contract No. F34650-93-D-0109, Order 5006* (Del City, Oklahoma: Woodward-Clyde Federal Services, for Air Force Materiel Command, July 1995).

[8] Mueller gives a date of 11 November 1943 for the name "Tinker Field." This appears to be a error. See Mueller, *Active Air Force Bases*, 1989, 545.

[9] Reise, *Tinker Air Force Base*, 1983, 19, 24.

[10] Julie L. Webster, Michael A. Pedrotty, and Aaron R. Chmiel, *Historical and Architectural Overview of Military Aircraft Hangars: A General History, Thematic Typology, and Inventory of Aircraft Hangars and Associated Buildings on Department of Defense Installations*, USACERL Technical Report 96, Draft (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, March 1996).

[11] J. Gordon Turnbull: "Midwest Air Depot Armament-Fire Control Supply & Repair Building," 1942; "Midwest Air Depot Engine Test Building," 3 February 1942. J. Gordon Turnbull's firm name, as well as that of Sverdrup & Parcel, also appears in the title blocks for buildings for which they had construction—but not design—responsibilities, such as the Airplane Repair Building and the Operations – Transport Squadron and Flight Test Hangar. Such practice was common, with drawings passed through the United States Engineer Office to the construction firm. The National Register of Historic Places nomination package for Buildings 230 and 240 incorrectly identifies "Turnbull, Sverdrup and Parcel" as the architects for both buildings: see, Charles M. Johnson, *Nomination Packages for Buildings 230, 240 and 4029 Tinker AFB Oklahoma City, Oklahoma Contract No. F34650-93-D-1019, Order 5020* (Del City, Oklahoma: Woodward-Clyde Federal Services, for Air Force Materiel Command, September 1996). The erroneous assumption is repeated in Woodward-Clyde Federal Services, *Tinker AFB Cultural Resource Management Plan* (Del City, Oklahoma: Woodward-Clyde Federal Services, for Air Force Materiel Command, January 2000).

[12] Reise, *Tinker Air Force Base*, 1983, 24-25, 27.

[13] Engineering Branch, Tinker Field, "Building & Street Layout," ca.1943.

[14] "Building Bases for Our Air Forces," *Engineering News-Record* 125, 17 (24 October 1940): 50-61.

[15] Air Materiel Command, *History of the Oklahoma City Air Materiel Area 1 July – 31 December 1955*, 244. In another example, the six-inch deep, reinforced concrete flooring of Building 3001, the Douglas aircraft assembly building of 1941, could not sustain the weight of the B-47, B-52, and KC-135 without modification. In 1959, contractors replaced a center 50-foot wide section of the flooring with reinforced concrete 17 inches deep. Schill, "The Early Years of Building 3001," 16 July 1999.

[16] Lenore Fine and Jesse A. Remington, *The Corps of Engineers: Construction in the United States*, volume in the *United States Army in World War II: The Technical Series* (Washington, D.C.: Office of the Chief of Military History, 1972), 640.

[17] Trnka and Manley, *Historic Building Inventory and Evaluation of Air Force Plant 4*, 1997, 3-28.

[18] Dan Schill, History Office, Tinker Air Force Base, "Building 230: Aircraft Maintenance to AWACS," *Tinker Take Off*, 6 March 1998.

[19] Reise, *Tinker Air Force Base*, 1983, 142.

[20] Air Materiel Command, *History Oklahoma City Air Materiel Area 1 July – 31 December 1951*, Installation XII, Part 1, 421-423.
[21] Air Materiel Command, *History Oklahoma City Air Materiel Area 1 January – 30 June 1951*, Installation XI, Part 1, 322-323.
[22] Charles M. Johnson, *Evaluation Report Historical Assessment Tinker AFB Oklahoma City, Oklahoma Contract No. F34650-93-D-0109, Order 5020* (Del City, Oklahoma: Woodward-Clyde Federal Services, for Air Force Materiel Command, August 1996), 3-13-3-16, with photographs.
[23] The only known complete set of drawings for the L.P. Kooken Special AMC Warehouse, including 62 individual drawings across the variations, is held in the civil engineering vault at Hill Air Force Base. Annotated card files at the History Office of the Army Corps of Engineers at Fort Belvoir should provide further information on the 33-02-01 commission and its follow-ons.
[24] "New Warehouse Contract Awarded: Work to Start," *Tinker Take Off*, 5 November 1954.
[25] *History Oklahoma City Air Materiel Area 1 July – 31 December 1951*, Installation XII, Part 1, 424.
[26] Drawings for Building 3705 include the title block "L.P. Kooken Co. Special AMC Warehouse 4/29/52," with "Adapted for Tinker AFB" added, and with Hudgins, Thompson, Ball & Associates given on selected drawings dated 30 January 1953.
[27] Dan Schill, History Office, Tinker Air Force Base, "Supply Warehouse Opens in 1954," *Tinker Take Off*, 4 December 1998.
[28] "New Warehouse Contract Awarded: Work to Start," *Tinker Take Off*, 5 November 1954.
[29] *History of the Oklahoma City Air Materiel Area 1 July – 31 December 1955*, 245; Mr. Patchin to W.L. Foster, "Request for Historical Information," exchange of questions and answers on civil engineering issues for preparation of the Oklahoma City AMA semiannual history, 14 and 19 June 1956.
[30] *History Oklahoma City Air Materiel Area 1 January – 30 June 1951*, Installation XI, Part 1, 331-332.
[31] Air Materiel Command, *History Oklahoma City Air Materiel Area 1 July – 31 December 1952*, Installation XIV, 359-362.
[32] Reise, *Tinker Air Force Base*, 1983, 144.
[33] "Background on Runway and closing of S.E. 59th Street south of Tinker AFB," one-page typescript, undated.
[34] *History of the Oklahoma City Air Materiel Area 1 July – 31 December 1955*, 245; Patchin to Foster, "Request for Historical Information," 14 and 19 June 1956.
[35] Dan Schill, History Office, Tinker Air Force Base, "Building 230: Aircraft Maintenance to AWACS," *Tinker Take Off*, 6 March 1998.
[36] Tactical Air Command, *History of 552nd Airborne Warning & Control Wing 1 October – 31 December 1976*, volume 1, 1-7.
[37] Tactical Air Command, *History of 552nd Airborne Warning & Control Wing 1 January – 30 March 1977*, volume 1, 5.
[38] Information on the EC-130 ABCCC is posted at www.fas.org/man/dod-101/sys/ac/ec-130e.
[39] *History of 552nd Airborne Warning & Control Wing 1 January – 30 March 1977*, volume 1, 1-3.
[40] Although not confirmed, the permanent command post is assumed to have been in Building 345, added to the flightline adjacent to the Building 230 / 240 area. The Air Force segregated Building 345 with its own security fencing, also omitting the structure from some printed maps.
[41] *History of 552nd Airborne Warning & Control Wing 1 January – 30 March 1977*, volume 1, 21, 33-37.
[42] Reise, *Tinker Air Force Base*, 1983, 111.
[43] Tactical Air Command, *History of 552nd Airborne Warning & Control Wing 1 January – 31 December 1978*, volume 1, viii-xi, 4-5, 10-11.
[44] Reise, *Tinker Air Force Base*, 1983, 145, 147, 151, 156-157, 160.
[45] Information on the E-3A is posted at www.boeing.com/defense-space/infoelect/awacs.
[46] Mueller, *Active Air Force Bases*, 1989, 552.
[47] Hudgins, Thompson & Ball, Inc., "Alert Facility – Buildings: Alert Crew Building," February and April 1982. Although not analyzed here, the alert area for the 6th ACCS did include other structures.
[48] C.H. Guernsey & Co., Oklahoma City, "E-3A Maintenance Hangar," June 1986.
[49] Information on the E-6 TACAMO (Take Charge and Move Out) is posted at www.boeing.com/defense-space/infoelect/e6.
[50] United States Army Corps of Engineers, "E-6A Hangar," September 1989.
[51] Graham Anderson Probst & White, Chicago, "Standard Type-Four Cell Jet Engine Test Facility," drawing E-100-259-003, 3 October 1951.

---

[52] Reise, *Tinker Air Force Base*, 1983, *passim.*
[53] *Ibid*, 145.
[54] Douglas C. McChristian and Jerome A. Greene, *Arsenal of the Cold War: A Survey of Potentially Significant Facilities on Property Administered by Hill Air Force Base, Utah* (Denver: National Park Service, for Air Force Materiel Command, December 1999), 113-114, 121-125.
[55] Reise, *Tinker Air Force Base*, 1983, 146, 149.
[56] Karen J. Weitze, *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970*, Holloman Air Force Base Cultural Resources Publication No. 5 (El Paso: Geo-Marine, Inc., for Air Combat Command, November 1997), 62-67.
[57] Information posted at www.fas.org/nuke/guide/usa/bomber/gam-63.
[58] Reise, *Tinker Air Force Base*, 1983, 146-148.
[59] Air Force Logistics Command, *History of the Oklahoma City Air Materiel Area 1 July 1961 – 30 June 1962*, volume 1, 150-151.
[60] *Ibid.*
[61] *Ibid*, 149, 153.
[62] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 172-174.
[63] Reise, *Tinker Air Force Base*, 1983, 118-119.
[64] Air Force Logistics Command, *History Oklahoma City Air Materiel Area 1 July 1960 – 30 June 1961*, Installment 29, Part 1, 152-153.
[65] Karen J. Weitze, "Building 810: Double-Cantilever Hangar," *Travis Air Force Base Fairfield California: Inventory of Cold War Properties* (Plano, Texas: Geo-Marine, Inc., for Air Mobility Command, October 1996), 69.
[66] Hudgins, Thompson, Ball & Associates, "Armament and Electronics Building," 2 March 1953; and, "Radar Sighting System," [for Building 201], 9 December 1953.
[67] "Construct a Collimator Pit in Building NR 205," 26 June 1956.
[68] Dan Schill, History Office, Tinker Air Force Base, "Years of Expansion Make Up Bldg. 201 History," *Tinker Take Off*, 3 September 1999.
[69] *History of the Oklahoma City Air Materiel Area 1 July 1961 – 30 June 1962*, volume 1, 161.
[70] *History Oklahoma City Air Materiel Area 1 July 1960 – 30 June 1961*, Installment 29, Part 1, 157-160.
[71] Reise, *Tinker Air Force Base*, 1983, *passim.*
[72] *Ibid*, 112.
[73] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 123.
[74] Information posted at usinfo.state.gov/topical/pol/arms/stories/01051701.
[75] Headquarters United States Air Force: *History of the Directorate of Civil Engineering 1 July – 31 December 1970*, volume 3, 118; and, *History of the Directorate of Civil Engineering 1 July – 31 December 1971*, volume 3, 112.
[76] *History of the Directorate of Civil Engineering 1 July – 31 December 1971*, volume 3, 112.
[77] Schill, "The Early Years of Building 3001," 16 July 1999, 11-12.
[78] Fine and Remington, *The Corps of Engineers: Construction in the United States*, 1972, 452-453.
[79] Henry F. Withey and Elsie Rathburn Withey, *Biographical Dictionary of American Architects (Deceased)* (Los Angeles: Hennessey & Ingalls, Inc., 1970), 20, 245-246, 491-492, 651-652.
[80] Information for GrahamAndersonProbstWhite, the contemporary form of the historic firm, is posted at www.gapw.com.

Chapter 14: Wright-Patterson Air Force Base

Historic Missions of the Cold War

Primary Missions

Throughout the Cold War, Wright-Patterson Air Force Base combined preexisting airfields into an unusual installation that functioned both as the headquarters for Air Materiel Command and its follow-on Air Force Logistics Command (AFLC), and as the leading base for Air Research and Development Command (ARDC) and its successor Air Force Systems Command (AFSC). Missions at Wright-Patterson run the breadth of both logistics, maintenance, and overhaul (Air Materiel Command / AFLC) and aeronautical research, development, testing, and evaluation (Air Materiel Command / ARDC / AFSC), with management of the activities at the depot and base levels, as well as oversight of the Air Force industrial plant program.

Tenant Organization Missions

In addition, Air Force tenants operated at Wright-Patterson, interwoven in a pattern tied not only to other major commands, but also to Headquarters Air Force in Washington, D.C. Major Cold War tenants with representative infrastructure on base included Air Defense Command (ADC) and Strategic Air Command (SAC). ADC sustained a regional command post on base and fighter-interceptor squadron (FIS) alert during the middle and late 1950s. SAC also maintained an alert posture at the installation from 1958 into the middle 1960s.

Chronology

From its beginnings associated with Huffman Prairie and the flight testing endeavors of Wilbur and Orville Wright, the air base near Dayton, Ohio, was physically and organizationally complicated. The Wright brothers had established an experimental flying field on part of what is today Wright-Patterson Air Force Base during 1904-1905, next setting up an aviation school on site between 1910 and 1916. With the onset of World War I, the War Department separately configured McCook Field, Wilbur Wright Field, and the Fairfield Aviation General Supply Depot in the immediate area (Plate 184). McCook Field existed to the north of downtown, evolving by mid-1919 as an engineering research center with strong ties to Langley Field in Virginia (see Volume I, Part II). Wilbur Wright Field and the Fairfield Aviation General Supply Depot occupied property adjacent to each other at today's Area C of Wright-Patterson Air Force Base. Fairfield was one of four major continental air depots established in 1917-1918 and complemented San Antonio (1917), Middletown, Pennsylvania (1917, with a repair unit added in 1926), and Rockwell [San Diego] (1917, moved to McClellan Field in Sacramento in 1937). The depot supported a Signal Corps Aviation School at Wilbur Wright Field, as well as three additional Signal Corps aviation schools in the Midwest.

The physical predecessors of Wright-Patterson changed again during the early 1920s when the Dayton Air Service Committee bought the acreage formerly leased to the federal government as Wilbur Wright Field. The committee augmented the land with additional acreage to the west. The combined purchase became Wright Field (see Plate 184). Late in the decade the Army constructed a new engineering center at Wright Field, replacing the outgrown facilities and associated runways at the McCook Field location. The Army Air Corps' Wright Field sustained aeronautical research and development (R&D) during the 1930s and hosted the Materiel Division that managed the procurement and maintenance functions of the Air Corps (see Volume I, Part II). Materiel Division oversaw six depots, including the Fairfield Depot in the years leading up to World War II. (In addition to the locational change from Rockwell Field to McClellan in California, by 1940 the Air

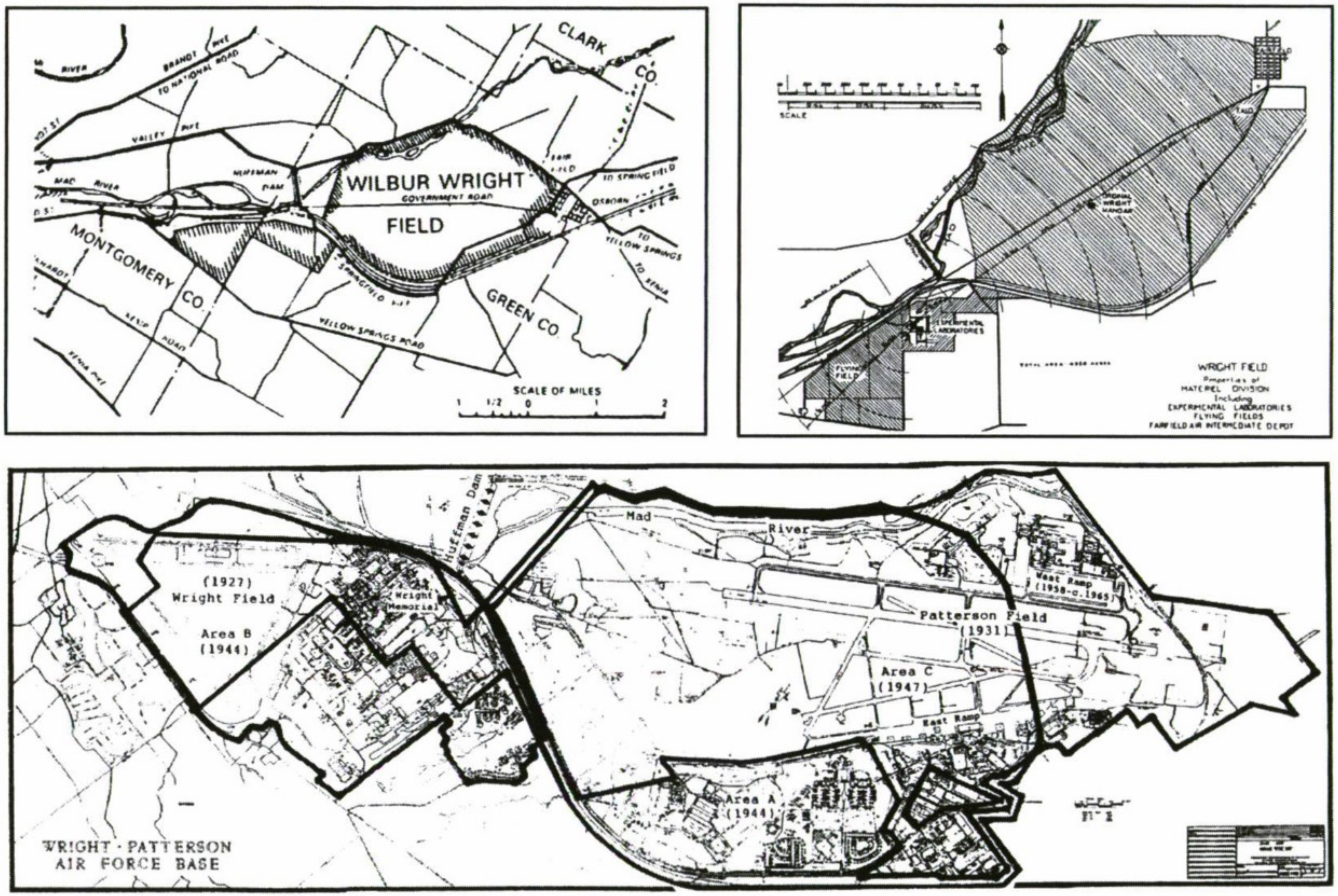

Plate 184: **Land Use Boundaries for Wilbur Wright Field (1917), Fairfield Aviation General Supply Depot (1917), Wright Field (1927), Patterson Field (1931), Wright Field, Areas A and B (1944), Patterson Field (1944), and Wright-Patterson Air Force Base, Areas A, B, and C (1948). Adapted from maps in *From Huffman Prairie to the Moon: The History of Wright-Patterson Air Force Base*, 1986, and, *Documenting the Cold War Significance of Wright Laboratory Facilities*, February 1996.**

Corps had expanded its network with depots in Alabama [at Mobile] and Utah [Ogden].) Wright Field's engineering center featured wind tunnels, temperature chambers, test stands, and other facilities advancing aeronautical progress. The installation was also home to the Air Corps Engineering School. An honorary (and organizational) change occurred during the early 1930s when the War Department renamed the logistics portion of the composite Wright Field and Fairfield Depot, east of the Huffman Dam, as Patterson Field (see Plate 184). From this date forward, the Fairfield Depot was absorbed within Patterson Field. Wright and Patterson Fields developed further during World War II. Wright Field continued as an R&D laboratory and test complex, while Patterson Field expanded in its logistics mission. Command lineage for the research and logistics halves at the two airfields changed several times during World War II, joined and separated, and finally linked together under Air Technical Service Command (1944) and subsequently Air Materiel Command (1946) (see Volume I, Part II). (The Army Air Forces alternately considered the name Air Logistics Command for Air Materiel Command, a name that would resurface in Air Force Logistics Command in 1961.[1]) The names "Wright Field" and "Patterson Field," as well as "Areas A and B," have physical land configurations tied to distinct periods of time. These designations are overlapping and complex. Area A was originally synonymous with Wright Field (1927), then Patterson Field (1931). The designations "Areas A and B" of Wright Field dated to August 1944. Area B was a straightforward redesignation of the airfield and experimental laboratories portions of Wright Field. A large portion of Patterson Field would become Area C in January 1948 at the time of the formal designation of Wright-Patterson Air Force Base.[2] Patterson Field included the original Fairfield Depot and most of the original Wilbur Wright and Wright Fields (see Plate 184). (In 2003, real property numbering is also tied to the Area A, B, and C designations: complete building numbers are five digits long, with those beginning in "1" in Area A, "2" in Area B, and "3" in Area C.)

As World War II ended, the Army Air Forces began to more completely integrate Wright and Patterson Fields. The Army Air Forces created Army Air Forces Technical Base, Dayton, Ohio, in December 1945. Two years later, after the establishment of an independent Air Force, the installation name changed slightly to Air Force Technical Base, and in mid-January 1948, to Wright-Patterson Air Force Base. At the outset of the Cold War, a strongly established R&D function, coupled with a logistics mission, defined the Technical Base in Dayton. The comprehensive Air Materiel Command missions of research, development, testing, and evaluation, and logistics-supply, operated at a major level for the Army Air Forces, and subsequently for the Air Force. Placing two distinctly different (albeit intertwined) major organizational structures at one physical location remained a challenge for the air base from 1945 forward. Somewhat hidden from historical observation was also a rich layering of technical and engineering precedents and accomplishments at the Dayton installation when World War II concluded. Many, if not in fact most, key aeronautical innovations had their roots in activities at Wright and Patterson Fields during the 1928-1945 period. Innovations ranged from those of sequentially improved aircraft to the intricacies of airborne weapons systems. Selected specialized base personnel analyzed aeromedical questions arising from high-altitude flight, while others turned their attentions to the infrastructure mandated to support future warfare capabilities.[3] Infrastructure for the rapidly advancing air age included runways, hangars, shops, and warehouses. At Wright and Patterson Fields (as well as in the cities of Dayton and Columbus, and at Dayton Army Air Field in Vandalia) were examples of engineering and design feats that would transition the Army Air Forces from the last years of World War II into the first decade of the Cold War. The Dayton-Columbus installations featured steel, reinforced concrete, and wood infrastructure that was among the most progressive in the United States during 1940-1945.

One illustrative example, among many, was experimentation toward runways suitable for the heavy bombers of late World War II, runways of even more complex specifications by the late 1940s. While engineering concentrated on breakthroughs made by leading State highway departments in the continental United States, and on work done through the Army Corps of Engineers Waterways

Experiment Station in Vicksburg, Mississippi, the first large-scale tests for scientifically calibrated reinforced concrete pavement were ones undertaken at Wright Field. (Backup control tests occurred at Langley Field in Virginia.) Rationale for the concentration of efforts in the upper Midwest, and in the Ohio River Valley in particular, included multiple facets. Civil engineers within the Ohio River Division of the Army Corps of Engineers had developed singular skills in concrete technologies and construction as a byproduct of a 1930s flood control program for the region. The Ohio River Division's state-of-the-art Concrete and Soil Mechanics Laboratories in suburban Cincinnati of the early 1940s offered facilities directly supporting airfield pavement studies. To the north of Wright and Patterson Fields was the renowned Portland Cement Association headquarters and technical engineering library in Detroit. Key architectural-engineering firms contributing to advances in military infrastructure during World War II were ones in Chicago and Detroit—a haven of expertise unlike any other in the country at the time. Important to the future Wright-Patterson and its commands, too, were the civil engineering departments of the University of Illinois in Champaign-Urbana, the Illinois Institute of Technology (IIT) in Chicago, the University of Michigan, Purdue University in Indiana, and the University of Cincinnati. Taking a leading role in the controlled testing of runway pavement at Wright Field in September 1941 was Dr. Nathan M. Newmark, a structural engineer at the University of Illinois.[4] Dr. Newmark would also contribute to *Toward New Horizons* in 1945, at the request of Dr. Theodore von Karman[5] (see Volume I, Part III). For the pavement experimentation at Wright Field, engineers first tested a seven-inch-thick reinforced concrete apron that had been laid on a clay subgrade in 1929, to the point of failure. In early October 1941, soil engineers were conducting additional tests on a concrete landing strip at the Dayton Municipal Airport (soon to be Dayton Army Air Field). By December, the Ohio River Division chief engineer oversaw the pouring of nine carefully designed concrete slabs of pavement at Wright Field, of varied thickness on differing subgrades. In both the Dayton Airport and Wright Field runway pavement tests of autumn 1941, an XB (experimental bomber) -19 flown in from Los Angeles served as the test aircraft. Wright Field reports were critical to later tests elsewhere across the United States. Often, a piece of heavy construction equipment (usually a Tournapull) simulated the pressures of a rolling bomber (see Volume II, Chapter 3). The Army geared all testing toward the B (bomber) -29 and B-36 to come.[6]

Other examples were hangars, shops, warehouses, and test spaces. Preeminent among the architectural-engineering firms working at Wright and Patterson Fields (including the Fairfield Depot), the depots in Dayton and Columbus, and Dayton Army Air Field in Vandalia were Austrian engineer Anton Tedesko (within Roberts & Schaefer of Chicago), Albert Kahn of Detroit, Norwegian engineer Fred N. Severud of New York, Allen & Kelley of Indianapolis, and Hazelet & Erdel of Chicago and Cincinnati. Wright-Patterson Air Force Base, coupled with Patuxent Naval Air Station in Maryland, contains the very best representation of Tedesko's engineering design achievements in the world (Plate 185), including:

- long-barrel, thin-shell reinforced concrete shops of 1942 (Building 20005 in Area B, alternately listed as a foundry and engineering shops on a Roberts & Schaefer's internal job list for North America) (see Plate 189),
- a long-barrel, thin-shell reinforced concrete hangar of 1942 (Building 20006 in Area B), and
- a five-bay, short-barrel, thin-shell reinforced concrete hangar of 1943 (Building 20004 in Area B) (see Volume I, Plates 3-4).

The thin-shell technology, known internationally as ZD [Zeiss-Dywidag] construction, derived directly from the 1920s-1930s experimentation of Dykerhoff & Widmann in Germany (see Volume I, Part II). Other important examples of Tedesko long-barrel, thin-shell reinforced concrete structures of the early 1940s were two large warehouse complexes in Dayton and Columbus (both substantially

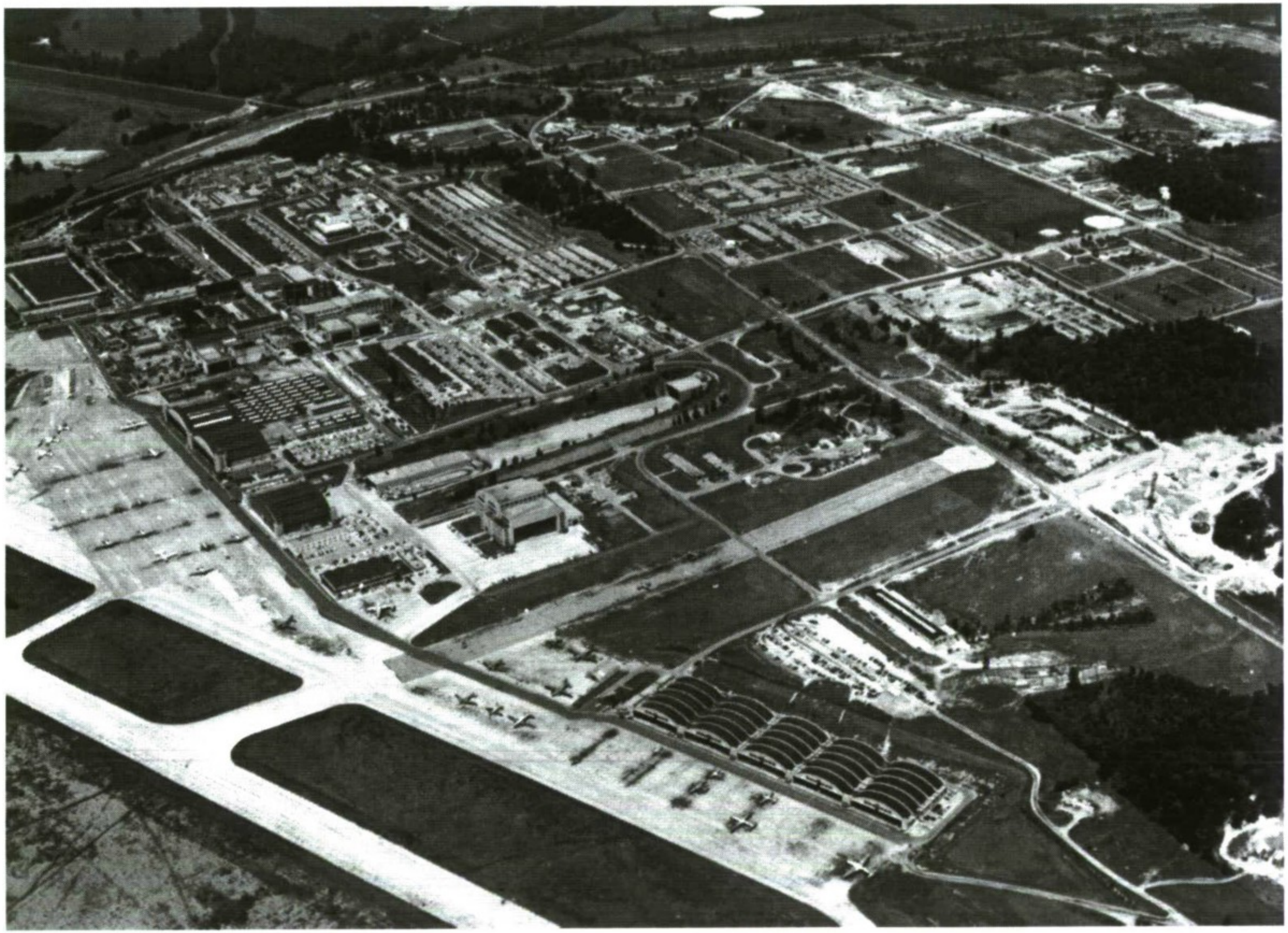

Plate 185: **Aerial View of Wright Field, 13 November 1943. Foreground, right of center: Building 20004. Middleground, center: Building 20065. Middleground, left: Buildings 20006, 20022, 20009, 20001, and 20005. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.**

altered)[7] (Plate 186). Tedesko was also among leaders in the engineering profession working with glue-laminated arch construction. *Engineering News-Record* described his four-bay hangars at Vandalia Army Air Field as having the longest known clearspan (177 feet) in the medium during World War II. The Vandalia hangars complemented Building 20004 at Wright Field. Both sets of structures served as flight test and research hangars. Those at Vandalia used a more cost-effective and quickly erected construction technology (Plate 187). All of Tedesko's structures in the Dayton area were ones executed to support a modification mission for Materiel Command and for its successor Air Technical Service Command, with the exception of Building 20006—a specialized testing hangar built for the Signal Corps. (Patuxent Naval Air Station commissioned 12 thin-shell hangars by Tedesko. Some of these were erected as electronics and radar test facilities.) Air Materiel Command, the follow-on to Air Technical Service Command in spring 1946, continued to hire major architectural-engineering firms for important and unusual commissions within the Army Air Forces, taking on Air Force-wide civil engineering oversight in mid-1947 (see Volume I, Part III). Almost simultaneously, Anton Tedesko designed a short-barrel, thin-shell hangar for maintenance of the B-36. SAC built the hangar at Rapid City (Ellsworth) and Limestone (Loring) Air Force Bases in South Dakota and Maine, respectively, during 1947-1949.[8]

Other very important infrastructure at Wright and Patterson Fields between 1940 and 1944 included the interconnected work of architect Albert Kahn and engineer Fred N. Severud, as well as a major design of the Army Quartermaster Corps. Kahn's outstanding achievements in steel construction for the Army during World War II (for manufacturing plants and hangars, among other assignments) included the Transport Squadron Hangar. Severud created its doubled variant of 1940-1941 by modifying the original Kahn design. The double hangar featured a center courtyard and was renamed the Operations – Transport Squadron and Flight Test Hangar (built at multiple depots of the command during the war) (see Volume II, Chapters 6, 7, 11, 12, and 13). Building 30206 at Patterson Field in Area C is an example of the Operations – Transport Squadron and Flight Test Hangar (Plate 188). The Operations – Transport Squadron and Flight Test Hangar would become the immediate precedent for Severud's B-36 hangar, the first hangar designed for the oversized bomber then still in development. The Army Air Forces erected Severud's B-36 hangar at three installations in the middle 1940s: Eglin Field in Florida, and San Bernardino Army Air Field (the future Norton Air Force Base) and Fairfield-Suisun Army Air Field (the future Travis Air Force Base) in California (see Volume I, Part II and Volume II, Chapter 4). Often found with the Transport Squadron Hangar / Operations – Transport Squadron and Flight Test Hangar at Army Air Forces depots was the Airplane Repair Building of the late 1930s, a tied steel arch structure of 275-foot span with depths varying from 190 to 250 feet. Designed and engineered through the Army Quartermaster Corps, the hangar featured prefabricated, modular components, easily shipped and erected as a standard facility across Army air depots between 1939 and 1944. The futuristic character of the hangar focused on the width and height of its aircraft doorway: 250 feet wide and 37 feet high, with an additional centered tail door of 15 by 15 feet. The Quartermaster Corps planned the Airplane Repair Building for the B-29.[9] The hangar was marginally capable of handling the B-36 during the challenging transitional years of the late 1940s. At Wright Field, Buildings 20001 and 20009, a pair of Airplane Repair Buildings (or, a two-bay structure) complemented the Operations – Transport Squadron and Flight Test Hangar for the Fairfield Depot.[10] In addition, a third Airplane Repair Building went up as the Armament Laboratory (Building 20022) during 1941-1942 to the south of Buildings 20001 and 20009. As built in the early 1940s, the Armament Laboratory contained hot and cold chambers, with some control for humidity testing and altitude conditions. By mid-1950, Building 20022 served as a starting point for the Cold War armament hangar designed by L.P. Kooken at Eglin Air Force Base.[11] The Airplane Repair Building appeared as single, double, triple, and quadruple units across the Army Air Forces, with the mature configuration two pair of hangars sited back to back with engineering shops between (see Volume II, Chapters 6, 7, 10, 11, 12, and 13). Unique at Wright Field was the combining of a

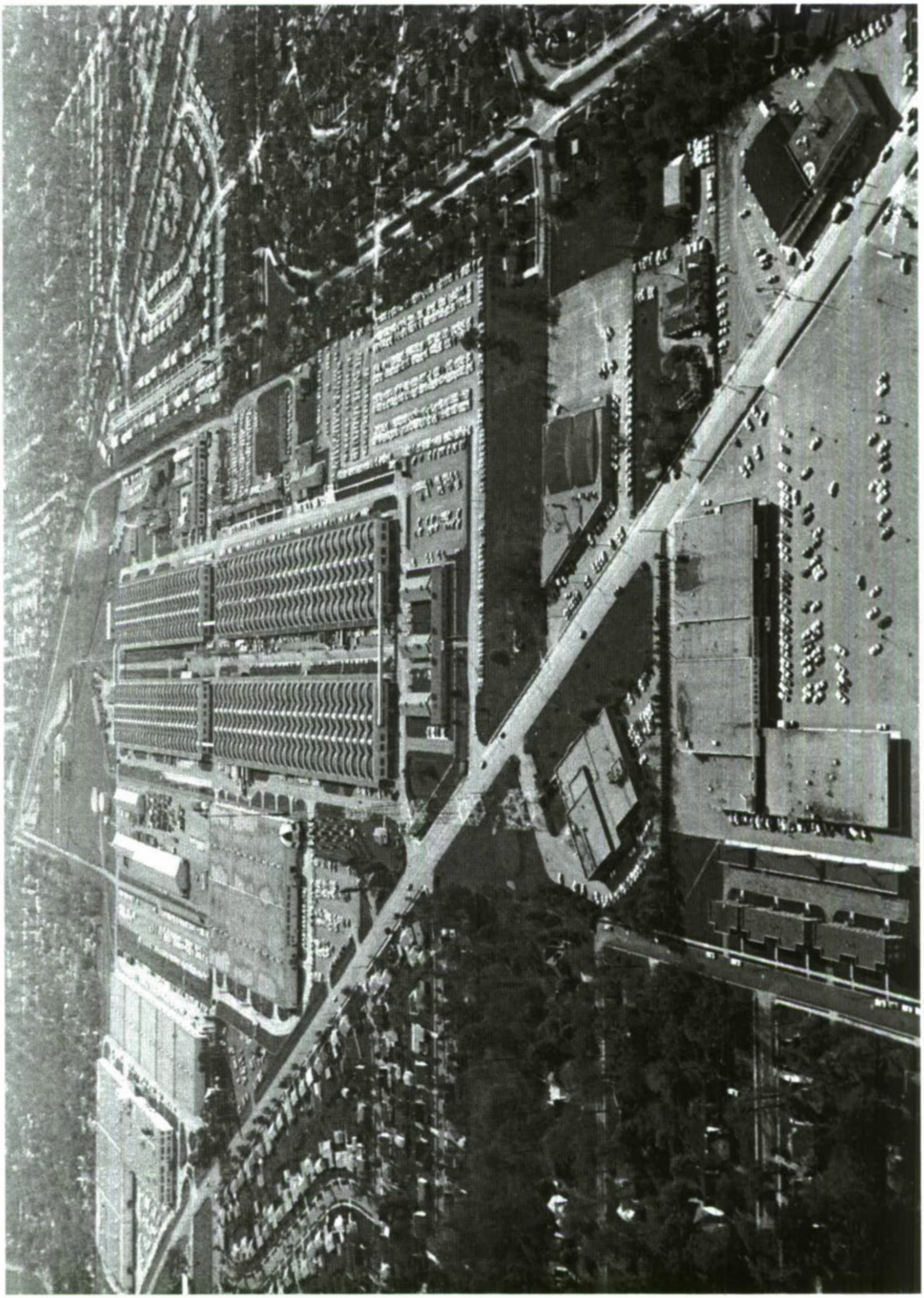

Plate 186: Aerial View of the Gentile Depot, Dayton, Ohio, undated. Middleground, center: Roberts & Schaefer (Anton Tedesko), Warehouse, 1940-1941. Background, left: L.P. Kooken, Special AMC Warehouse, 1952. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

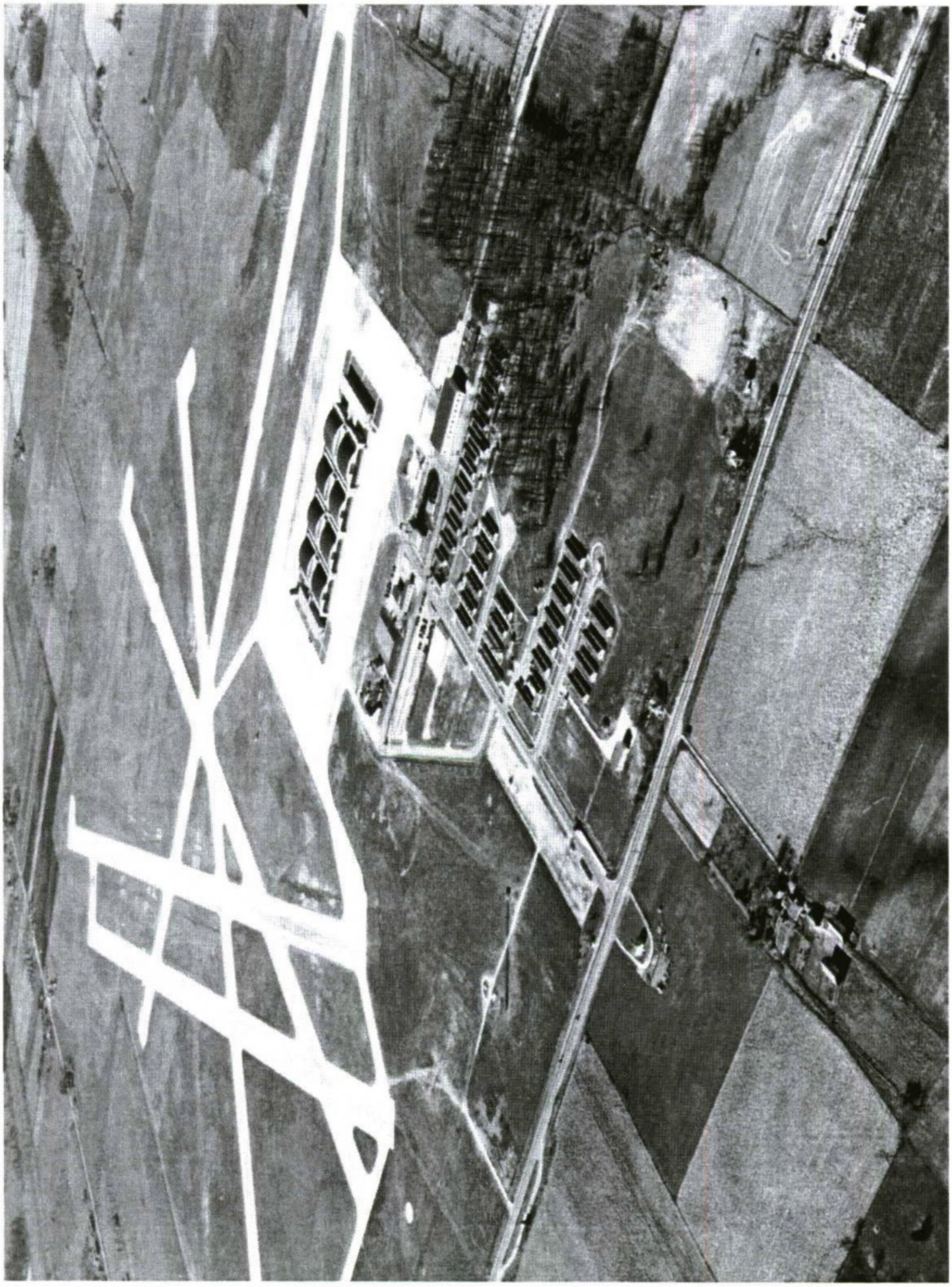

Plate 187: Aerial View of Vandalia Army Air Field (Dayton Army Air Base), Vandalia, Ohio, 18 March 1943. Middleground, center: Anton Tedesko, Glue-Laminated Wooden Modification Hangars. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

Plate 188: Fred N. Severud. Operations – Transport Squadron and Flight Test Hangar (Building 30206), Patterson Field, 1940-1941. (Improved from Albert Kahn's Transport Squadron Hangar of 1940.) Photograph of 7 January 1952. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

standard double Airplane Repair Building (Buildings 20001 and 20009) with the thin-shell concrete shops designed by Tedesko (Building 20005) (Plate 189). Nowhere else are the two progressive designs combined.

Two final key architectural-engineering firms working at Wright and Patterson Fields during World War II were Allen & Kelley and Hazelet & Erdal. Both firms, like Roberts & Schaefer (Tedesko), would be among the earliest architectural-engineering partnerships hired through Air Materiel Command for unique or unusual building commissions required by the Army Air Forces and Air Force during the late 1940s. Air Materiel Command considered Allen & Kelley and Hazelet & Erdal among a short list of possible firms for its underground pilot plant of 1948-1949, a project that required expertise in heavy reinforced concrete construction technology. (The other architectural-engineering firms making the short list were Blaw Knox of Pittsburgh, Giffels & Vallet of Detroit, J. Gordon Turnbull of Cleveland, and Sverdrup & Parcel of St. Louis. J. Gordon Turnbull won the assignment) (see Volume I, Part III).[12] Allen & Kelley and Hazelet & Erdal were each responsible for important work on base. Allen & Kelley designed the Propeller Laboratory (Building 20020A) of 1941-1944, a cast-in-place reinforced concrete structure with walls two feet thick that combined solid construction with honeycombed acoustical baffles (see Plate 189). (The Propeller Laboratory's three test stands of 1929-1931 had originally stood in the open.) Air Materiel Command later hired Allen & Kelley to add a fourth test stand inside the laboratory during 1951. Hazelet & Erdal's Static Test Laboratory of 1943-1944 (Building 20065) was also an overbuilt reinforced concrete and steel structure. Building 20065 accommodated the B-36 fuselage and wing span, in a sideways positioning—with room to flip and rotate the fuselage completely (see Volume I, Plate 7). Hazelet & Erdal's test facility, like that of Allen & Kelley, looked toward Cold War needs. The structure's

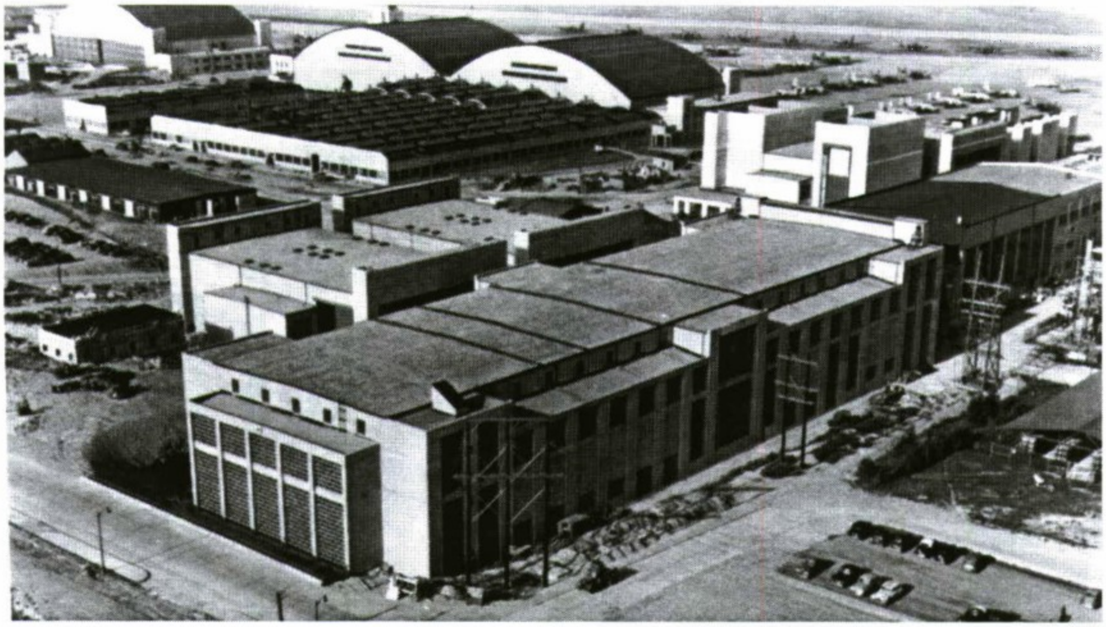

Plate 189: Allen & Kelley. Propeller Laboratory (Building 20020A), Wright Field, 1941-1944. Background, left to right: Buildings 20022, 20009, 20005, and 20001. Photograph of 1944. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

foundation featured a 30-inch reinforced concrete slab, with a sub-base of solid rock (Plate 190). In 1946, the command next hired Hazelet & Erdal for a significant laminated wood-arch structure for controlled radar testing (see below).[13]

The concentration of architectural and engineering excellence for infrastructure at Wright and Patterson Fields during 1940-1945 reflected more than random coincidence, mirroring transitional relationships between the Quartermaster Corps of the Army, the Army Air Corps, and the Army Corps of Engineers—relationships that would further evolve between the Materiel Division / Air Materiel Command of the Army Air Forces / Air Force, and the Army Corps of Engineers. Following World War I, assignment of construction duties for the Army fell to two entities, the Quartermaster Corps and the Corps of Engineers. Generally, the Quartermaster Corps handled cantonments and military housing, with the Corps of Engineers responsible for heavy construction projects. The two agencies within the Army competed for sole jurisdiction over the civil engineering mission throughout the 1920s and 1930s. The Quartermaster Corps relied on contracting to the private sector, with a weak over-centralized system of organization. In contrast, the Corps of Engineers had established vibrant regional divisions, operating a decentralized network with an internal staff of well-trained engineers. The Quartermaster Corps was part of a supply bureaucracy, with fewer and fewer of its own building and construction professionals after the middle 1920s. In addition by the unfolding emergency of 1939, the Air Corps moved to handle its own construction for airfield installations within the Army. At Wright and Patterson Fields, the independent behavior of the Air Corps combined with a very strong regional Corps of Engineers division, that of the Ohio River. The installations were also physically located in proximity to Detroit and Chicago, important centers for concrete construction technology and for vibrant architectural-engineering design. By mid-1939, the desire for improved Air Corps buildings and structures led to the removal of their construction mission from the Quartermaster Corps—placing civil engineering responsibilities for the

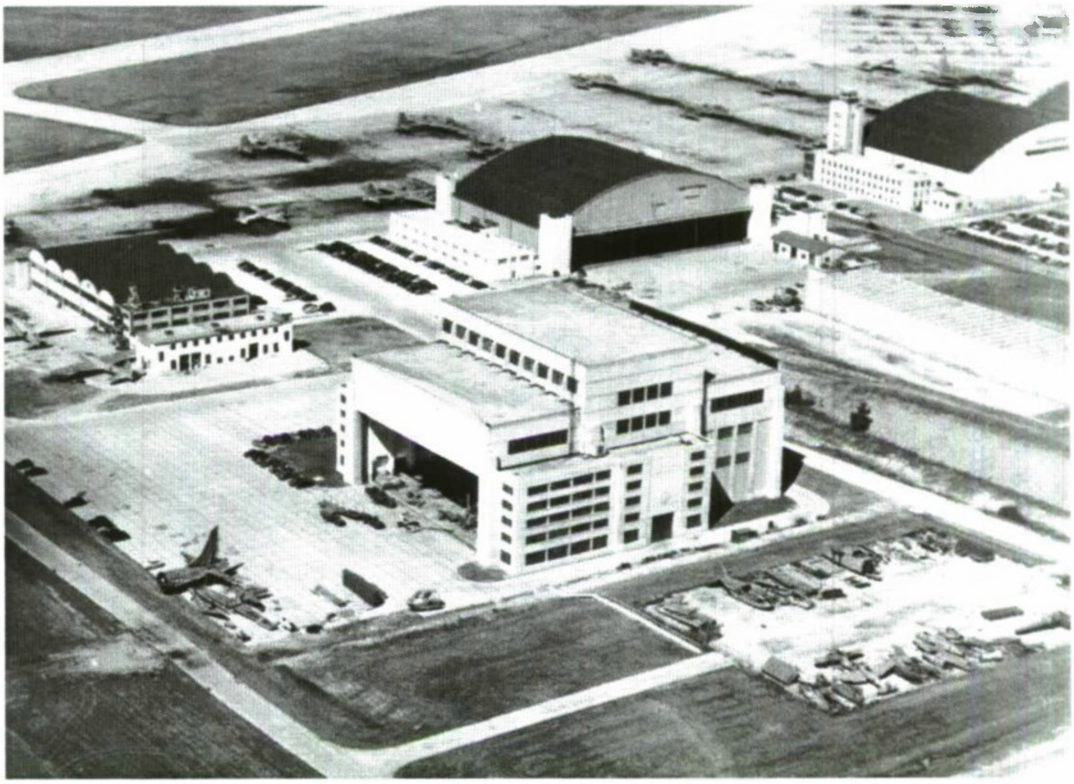

Plate 190: Hazelet & Erdal. Static Test Laboratory (Building 20065), Wright Field, 1943-1944. Background, left to right: Buildings 20006, 20022, and 20009. Undated photograph. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

Air Corps directly under the Corps of Engineers (with runways, hangars, and technical structures henceforth considered "fortifications").[14]

The fledging construction group within the Materiel Division of the Air Corps did not integrate well with the Corps of Engineers, while the working methods of private contracting established through the Quartermaster Corps kept all three corps in competition for the air depot civil engineering tasks. In March 1941, representatives of the Materiel Division of the Air Corps and the Ohio River Division of the Corps of Engineers met at Wright Field, evaluating inadequate Quartermaster Corps drawings and plans and deciding to hire Graham, Anderson, Probst & White of Chicago to begin the process of achieving first-rate Air Corps depots (see Volume II, Chapter 13).[15] After this date, other major architects and engineers, predominantly of the upper Midwest and with several of international standing, also undertook work for air depots, with a civil engineering mission for the Army's air arm coalescing at Wright Field. Even subsequent to the full transfer of the Army's construction program to the Corps of Engineers in late August 1941 (with the absorption of the Construction Division of the Quartermaster Corps and the formation of the United States Engineer Office), a civil engineering independence appears to have remained at Wright Field even as the Air Corps became the Army Air Forces. The increasing autonomy of the Army Air Forces within the Army only intensified the unfolding development, with an Air Installations Division subsumed under the supply mission of Air Technical Service Command in mid-1945. Air Installations at Wright and Patterson Fields took on a significantly increased importance during 1946, when the War Department eliminated the Army Service Forces. As a by-product of a long evolution in this direction, Headquarters Air Materiel

Command at Wright Field through T-4, Supply (see below) received full Army Air Forces responsibilities for

> [former] Corps of Engineers services—construction, real estate, and repairs and utilities responsibilities—as well as the master planning program...The success with which the AAF [Army Air Forces] took over these functions was critical to AAF autonomy objectives.

During 1946, Air Installations staff at Wright Field varied from 94 to 135 persons and oversaw more than 10,000 Air Materiel Command civil engineering personnel across Army Air Forces installations.[16] With the creation of the Air Force in mid-1947, Headquarters Air Force in Washington, D.C., formally assigned the Air Force Technical Base in Dayton (soon to be Wright-Patterson Air Force Base) continued responsibilities for civil engineering across the Air Force through the Air Installations Division at Headquarters Air Materiel Command—setting up an entity within the Air Force parallel to the Army Corps of Engineers and harkening back to the headstrong independence of the Air Corps in the late 1930s. During the early decades of the Cold War, the Corps of Engineers did not play the role often assumed for Air Force construction. Instead, efforts through Headquarters Air Materiel Command at Wright-Patterson were of pivotal importance (see Volume I, Part III).

In 1944, the two "halves" for today's Air Force Materiel Command were in place at Wright and Patterson Fields, setting the immediate stage for the role of Wright-Patterson Air Force Base during the Cold War. That year Air Technical Service Command replaced Materiel and Air Service Commands at Wright and Patterson Fields, respectively—which themselves had superceded the Materiel Division of the Air Corps / Army Air Forces. (Technically, the supply and procurement mission of Materiel Division had briefly moved into Maintenance Command, Provisional, established within the Air Corps during March-April 1941 and followed by Maintenance Command into late 1942. It was this part of Materiel Division that became Air Service Command.) The Army Air Forces situated Headquarters Air Technical Service Command at the paired airfields, directly following the April 1943 placement of Headquarters Materiel Command at Wright Field. A year later, the Army Air Forces designated its base units in a numerical 4000 series, with the 4000 AAF Base Unit (Command) established at Wright Field. The 4000 AAF Base Unit (Command) combined all former squadrons of enlisted personnel at Headquarters Air Service Command, with the exception of two all-black squadrons at Wright Field (the 351st and the 371st Aviation Squadrons)—the latter remaining segregated as the 4900 AAF Base Unit (Aviation Squadron).[17] The logistics-supply mission within Air Technical Service Command streamlined overlapping service and depot areas, also reforming the organizational hierarchy of depots, storage areas, and logistics installations as well as the cataloguing of stock inventory (see Volume I, Part II).

During 1945, Patterson Field served as one of 12 materiel centers for the Army Air Forces. In January, months before victory in Europe at mid-year and victory in Japan in the autumn, Air Technical Service Command at Wright and Patterson Fields managed over 650,000 different aeronautical spare parts and equipment categories across its installations, with predictable problems in accurately identifying and tracking its stock balances. Need for a worldwide stock control system was imminent. Too, between January and December 1945, Air Technical Service Command augmented its storage responsibilities for aircraft from 3,551 to 15,688 planes, a situation aggravated by a lack of experience in long-term aircraft storage.[18] With the war near its end, Air Technical Service Command instituted a T (technical [?]) -Staff system of bureaucracy in July and established the Army Air Forces Technical Base, Dayton, immediately following the war in December. Army Air Forces Technical Base, Dayton, included the combined Wright and Patterson Fields, with jurisdiction for Clinton County Army Air Field at Wilmington, just southeast of Dayton, and Dayton

Army Air Field at Vandalia to the northwest.[19] Within the T-Staff system, T-4 handled the broad supply and procurement mission at the base. This format continued as Air Technical Service Command transitioned to Air Materiel Command during spring 1946. (A portion of the logistics-supply mission also lay within T-3, Engineering. See Volume I, Part II.) The procurement mission within T-4 oversaw three procurement districts, as well as the network of aircraft industrial plants established for wartime production.

During the late 1940s, the first Cold War endeavors of the supply-logistics half of Air Materiel Command were ones supporting demobilization following the victories in World War II, focused on storage, salvage, and sale of military equipment; and, consolidation of the system of primary depots—each with jurisdiction over a respective Air Materiel Area (AMA). The Fairfield Air Depot (within Area C of Patterson Field) had officially deactivated in January 1946 under Air Technical Service Command, with its operations transferred to the Middletown AMA at Olmsted Air Force Base in Pennsylvania. Wright Field (in 1948, Wright-Patterson Air Force Base) continued as the headquarters location for Air Materiel Command. As a part of its supply-logistics mission, the command further refined its general depot network and distribution system, moving to a two-zone supply umbrella, and maintaining a pre-Korean War plateau of seven primary depots, five specialized depots, and two main aircraft storage fields—all managed out of Wright-Patterson (see Volume I, Part II). Personnel at Wright Field had flight tested not only American aircraft during the war, but also foreign military planes, another role continued during the late 1940s until much of this function moved to Muroc Field (Edwards Air Force Base) in Southern California. Using facilities at Wright Field, the Flight Test Division of 1946 oversaw maintenance on administrative aircraft stationed at Wright and Patterson Fields, foreign and experimental aircraft at Wright Field, glider aircraft transferred from Freeman Field in Indiana, and aircraft associated with the All-Weather Flying Center at the Clinton County Air Field.[20] Air Materiel Command also increasingly employed the hangars and aircraft laboratories at Wright Field for specialized component and instrument testing, including evaluations of the B-36 fuselage in the Static Test Laboratory (see Volume I, Plate 7). Adding new buildings for this type of mission became an immediate concern in 1946.

Headquarters Air Technical Service Command (1944) / Air Materiel Command (1946) at Wright Field also initiated efforts toward next-era aeronautical research, development, testing, and evaluation as the Army Air Forces transitioned from World War II into the Cold War. Research and testing important for the decades ahead first became focused at the outset of 1944, tied to the particulars of weapons advancement, aircraft development, and larger geopolitics. One of the earliest steps toward Cold War missiles, for example, was the shipment and study of captured German V (Vergeltung / Vengeance) -1 parts to Wright Field in July, where Army Air Forces engineers and wartime contractors duplicated the V-1's pulsed jet engine and worked on possible launch configurations. Air Technical Service Command and its follow-on Air Materiel Command tested the resultant guided missile, the JB (jet bomb) -2, on a special range at Eglin Field (see Volume II, Chapter 4), at the Wendover Bombing Range in Utah, and, beginning in late 1947, at Alamogordo (Holloman) Air Force Base in New Mexico. Another example of coalescing needs within the command concentrated on testing in an artificially stable environment. While the winter of 1942-1943 had been crippling for military aircraft in northern Europe and at the Russian Front, the winter of 1943-1944 had been abnormally warm—proving that tests run outdoors in Alaska were unreliable. The Cold Weather Liaison Office at Wright Field had been overseeing tests at Ladd Field in Alaska as of 1940, but by April 1944 planned for a controlled test chamber coordinated with the Arctic, Desert and Tropic Information Center at the Air Proving Ground at Eglin. Air Technical Service Command / Air Materiel Command erected a climatic hangar at Eglin capable of accommodating the B-36 (not yet deployed) between 1944 and 1947. Air Materiel Command first tested the aircraft in the facility in May 1947.[21] Successful flight at very high altitudes, and in the extended frigid conditions characterizing winters in the Soviet Union, was a benchmark of the early Cold War. Other cold-

weather test sites supervised by Air Materiel Command included ones at Clinton County Airfield, the Mount Washington Ice Research Facility in New Hampshire, and the Aeronautical Ice Research Laboratory at Willow Run, Michigan. In 1947, the command added a strato-chamber in the Armament Laboratory (Building 20022) at Wright Field. Both the Eglin and Wright Field hangars almost immediately also included extreme hot-weather testing capabilities, with the Florida facility designed for whole-aircraft hot and cold tests[22] (see Volume I, Part II and Volume II, Chapter 4). Both humid- and dry-climate analysis was of concern to the command. In preparation for hot-weather testing, Air Materiel Command set up a tropical science mission using a specially outfitted C (cargo)-54 as a flying laboratory that "toured tropical areas to make general observations and collect specimens for shipment to the AMC [Air Materiel Command] laboratories." Other tests of 1946 included ones directed at desert environments where actinic agents and fungi were important considerations.[23]

The T-Staff system of mid-1945 not only defined the logistics half of Air Technical Service Command (as T-4, Supply, and a component of T-3, Engineering) at Wright and Patterson Fields, but also included a sizable R&D hierarchy through T-2, Intelligence and T-3, Engineering. T-2 became the core of a foreign analysis division, with initial missions centered on documents and equipment shipped from Germany as the war ended in Europe. During spring 1945, following formative discussions and setup at the behest of General Henry "Hap" Arnold, Dr. Theodore von Karman led a group of scientists on a research trip to northern Europe to meet with captured German scientists and to visit military aeronautical laboratories. Von Karman's endeavors, supported through the framework of the Scientific Advisory Group (SAG), led to the overall program organization for R&D within Air Materiel Command (and in 1950-1951, to the separation of the logistics-supply mission as Air Materiel Command and that of aeronautical research as ARDC) (see Volume I, Parts II and III). Dr. von Karman had also reviewed collected materials held in the Air Documents Research Center in London, the repository for German technical documents stored and copied for Allied use. In November 1945, the operations of the Air Documents Research Center physically relocated to Wright Field. The 60,000 scientific documents, many reproduced as microfilm and translated from German, became the genesis of the intelligence mission at Wright-Patterson[24] (see Volume I, Part II). By the late 1950s, a separate cluster of buildings on base housed the foreign intelligence mission. Key Cold War structures among the intelligence group were Buildings 10829, 10856, and 10858. Freeman Field in Seymour, Indiana, served as a storage depot for technical intelligence materials until October 1946, when Air Materiel Command transferred these items to the 803rd Specialized Depot in Chicago. The Air Documents Division of T-2 at Wright Field also initiated preparation of a German-English scientific dictionary during 1946.[25] (Air Materiel Command stored foreign aircraft at Freeman Field until mid-April 1947.[26]) From 1945-1946 forward, especially through the 1950s, contracted German scientists of Project Paperclip contributed to the intelligence mission, working at Wright-Patterson in large numbers generally (see Volume I, Part III).

During these same seminal years into the early 1950s, a research, development, testing, and evaluation mission within Air Materiel Command expanded significantly, with the beginnings of the full network of research and test installations underway. Centers unfolded with discrete missions: armament (at Eglin), radar and electronics (at the Watson Laboratories in New Jersey, the Cambridge Field Station / Research Laboratories / Research Center in Boston [later, moved to Hanscom Air Force Base in Massachusetts], and Griffiss Air Force Base in New York), flight testing (at Edwards), guided missiles development (at Holloman) and testing (at Patrick Air Force Base in Florida), long-range missile and space weapons development (at Los Angeles Air Force Station / Base), special weapons development (Kirtland Air Force Base in New Mexico), wind-tunnel, static test stand, space chamber, and other precision components testing (the Arnold Engineering Development Center [AEDC] in Tennessee), and aeromedical research (Wright-Patterson, Holloman, and Brooks Air Force Base in Texas). At Wright-Patterson, the Wright Air Development Center (WADC) undertook

a broader variety of endeavors (see below), and until June 1951 the WADC was responsible for the mission-specific centers at Edwards, Griffiss, Hanscom, and Holloman (see Volume I, Parts II and III). In the late 1940s, the grouping of research bases also included the participation of a number of short-lived installations, predominantly tied to radar, cold-weather testing, and guided missiles, and all managed by Air Materiel Command at Wright-Patterson. Ties to the National Advisory Committee for Aeronautics (NACA) continued liaisons long-present for the Dayton installation, with these sustaining their strength as NACA evolved into the National Aeronautical and Space Administration (NASA). Other specialized endeavors were numerous. Within T-3, Engineering, Air Materiel Command organized the Army Air Forces Institute of Technology in December 1945, an educational institution growing out of the preexisting Air Corps Engineering School[27] (see Volume I, Part III). The command's R&D half also addressed atomic, biological, and chemical weapons development, including efforts toward protective and hardened construction. One example of 1948-1949 was the command's sponsorship of an underground pilot plant, paralleling similar exploration by the Army, while another was work with Holabird, Root & Burgee on the first Cold War system of command posts for ADC (see Volume I, Parts III and IV). At the threshold of the Cold War, Air Materiel Command spent about 15 percent of its T-3, Engineering budget on "required fundamental research," and the remaining 85 percent on equipment development. Of these monies, 80 percent went to R&D contracts with universities and nonprofit organizations (for research) and industry (for development).[28] World War II research run through the National Defense Research Committee (NDRC) also heavily shifted to Air Materiel Command (see Volume I, Part III).

During 1945-1947, Air Materiel Command planned for the era ahead at Wright and Patterson Fields. Removal of the supply and maintenance missions at the Fairfield Depot made possible a reuse and expansion of its facilities for "engineering, development, and flight test articles."[29] In the *Preliminary Master Plan Report* approved by the Army Air Forces Technical Base Planning Board in mid-March 1947, Air Materiel Command set forth its intentions for a "VVHB" runway. In this period all references to a Very, Very Heavy Bomber (VVHB) were for the B-36, and the availability of appropriately constructed reinforced concrete runways presented urgent problems for all installations planned for receipt of the bomber. Colonel Frank M. Kennedy, chief of the Air Corps' Buildings and Grounds Division (and an engineer), had opposed the shift of infrastructure design and engineering from direct Air Corps control to the Army Corps of Engineers, and had imposed many of his own ideas upon the Air Corps while they sustained autonomy. Among other design concepts, Colonel Kennedy had desired all-concrete runways. While the Army Corps of Engineers had supported reinforced concrete runway technology for heavy bombers, the Corps of Engineers had more often addressed soils and sub-base studies, as well as the appropriate uses of asphaltic and soil-cement runways.[30] Evaluation of rigid-design runways was in somewhat of a hiatus between 1941 and 1942, and only in the summer of 1942 did the head of the Ohio River Division's Soil Mechanics Laboratory in Cincinnati, Robert R. Philippe, call for a comprehensive examination of reinforced concrete runway engineering. Trained at the Massachusetts Institute of Technology (MIT), Philippe had become worried about rigid-design runways for future heavy bombers (which would first include the B-29, and later the B-36) after further reviewing the testing done at Wright Field in 1941.

The World War II test pavement at Wright Field featured slabs eight inches thick, with a thin base course—assumed to be the correct structural design for subsequently constructed runways across the country. But by the summer of 1943, reinforced concrete runways designed for B-29s were failing under lesser loads. The situation stimulated a new round of study. That year Philippe planned a large, sophisticated reinforced concrete oval test track at Lockbourne Field (later, Lockbourne / Rickenbacker Air Force Base) in Columbus, thereby setting up a second major rigid-design runway test project for the Army Air Forces in Ohio. (Boeing delivered the first of the operational B-29s in June 1943.) By mid-1944, after inquiries by General Arnold into runway strengths for the future B-36, Philippe built another experimental runway facility at Lockbourne. The second test runway at

Lockbourne was comprised of nine concrete slabs varying in thickness from 12 to 24 inches—both reinforced and unreinforced, with selected slabs also including second-story overlays (a common method in the late 1940s for beefing up runways in the short term for the B-36).[31] The Lockbourne pavement studies of 1944-1945 led directly to plans for the VVHB runway of 1947 at Patterson Field. At Wright and Patterson Fields, where flight testing and maintenance had supported the heavier bombers and experimental aircraft of World War II, the early 1940s runways were of reinforced concrete construction, but were of standard length (varying from about 5,570 feet to 7,148 feet, and each 150 feet wide) and strength.

While pavement testing of 1941 had occurred at Wright Field—with an additional 10-percent inclined runway also in place (see Volume I, Parts II and III, and Plate 8), Air Materiel Command planned a VVHB runway at Patterson Field. Limited load conditions for take-offs on runways at both fields had curtailed flight testing and general operations for B-29s by 1947. The master plan called for a new 15,000-foot long runway at Patterson Field, 500 feet wide. The command first intended to construct 8,000 feet of reinforced concrete runway, with two 1,000-foot overruns at each end (underway in 1947). The initial runway was to be 300 feet wide, running northeast-southwest and paralleling the early 1940s northeast-southwest runway, which would become a taxiway. A second phase would extend the VVHB runway 4,000 feet on its northeast end and 1,000 feet at the southwest. In a final phase, workmen would widen the runway on each side by an additional 100 feet of reinforced concrete (to the planned maximum of 500 feet). Capacity loading was 300,000 pounds, the weight anticipated for the B-36.[32] The Patterson Field runway was among the earliest runways engineered for the bomber, and may have been the first such runway scientifically engineered in its sub-base and reinforced concrete rigid design. (Initial "B-36 runways" dated to 1945: at Carswell Field in Fort Worth, where the B-36 was in manufacture, and at Eglin Field in Florida, where the bomber would undergo tests at the Air Proving Ground.) In early 1948, Wright Field and Patterson Field became absorbed within the new designation of Wright-Patterson Air Force Base. The runways associated with the two airfields, however, remained more easily referenced by the earlier naming system.

The Patterson Field runway featured reinforced concrete paving 21 inches thick. The adjacent taxiways and warm-up area were 25 inches thick. Reinforcement was more nominal than that present in the eight-inch slabs of World War II, while subgrade was much expanded. In preparation for the two sequential concrete pours, workmen removed one to five feet of unacceptable soil and rock on site, replacing it with selected materials compacted with sheepsfoot rollers. Robert Philippe at the Army Corps of Engineers' laboratory in Cincinnati and the engineers at the Corps' Louisville District shared joint design responsibility for the $5,000,000 runway project.[33] The experimental version of the B-36A, the XB-36, arrived on base in August 1947 for static tests, although documents do not indicate how or where the bomber landed.[34] On 31 December, the Air Force formally declared the new Patterson Field runway to be completed. By autumn 1948, test personnel at Wright-Patterson intended to move a B-36 from Area C (of the former Patterson Field) to Area B (of the former Wright Field), where they planned "to place 20-pound charges of TNT in the fuselage to see the extent of the damage." While the Wright-Patterson Air Force Base Planning Board noted that transferring large aircraft to the World War II engineering test shops and hangars in Area B could not be "safely" accomplished, the board gave no indication as to how workmen carried out the feat—even unsafely.[35]

A runway 15,000 feet long in 1948 would have been remarkable, and would be equally in 2003. The longest runways among the test bases within the Air Materiel Command network were those at Kirtland and Edwards. The Air Force improved the runway at Kirtland through overlays and extensions to 10,000 feet in 1948 (explicitly for the B-36) and planned a new runway for Edwards in 1951. At Kirtland, a fully new runway for the B-36 and B-52 went in place in 1954: 13,773 feet long and 300 feet wide. At Edwards, Air Materiel Command built a runway 15,000 feet long (300 feet

wide) at the same time. The Kirtland runway featured a subgrade of 17 to 20 inches of compacted earth, a base grade of eight to 13 inches of stone and gravel, and a top paving of four inches of asphalt. The Edwards runway, like that at Patterson Field, was reinforced concrete construction, with the concrete paving 17 to 19 inches thick. Engineers designed the Edwards runway for 500,000 pounds of aircraft weight, also taking advantage of a natural extension onto the dry lake bed to configure a usable runway to 16,800 feet 10 months of the year (see Volume II, Chapters 3 and 8). Headquarters Air Force defined a VVHB runway as necessitating a "practical length" of 11,000 feet, with 300 feet the typical width. At Patterson Field, Air Materiel Command constructed only a 10,000- by 300-foot runway (lengthened to 11,000 feet through 1,000 feet of paved overrun). By October 1957, one of two master plans for Wright-Patterson illustrated the runway at Patterson Field as including 4,000 feet of unpaved overrun at one end of the runway, and 1,000 feet at the other, but with intentions for abandonment of these overruns. The second master plan of Wright-Patterson at this same time showed that runways at Wright Field continued to be those of World War II. A most intriguing proposal included in the two master plans of the period was for an extension of the early 1940s inclined runway at Wright Field (in Area B), cutting across the Erie and New York Central Railroad and connecting to a major new apron area paralleling the primary runway at Patterson Field (in Area C)[36] (Plates 191-192).

The layout of the VVHB runway at Patterson Field of 1947 also stimulated plans for new flightline hangars, with a command assumption that the existing Operations – Transport Squadron and Flight Test Hangar (Building 30206)—the only major hangar on the World War II flightline at Patterson Field —would be obsolete due to its siting and the "increased physical dimensions of the aircraft and the volume of traffic...[it]...will be required to accommodate." The planned late-1940s Cold War flightline for Area C at Patterson Field was never constructed, but was evocative of the first Air Force intentions for the B-36. The *Preliminary Master Plan* of 1947 listed a VVHB hangar (to house four B-36s), fighter hangar, and operations tower-and-hangar. The plan described the three structures as: 400 by 600 feet, 200 by 400 feet, and 260 by 900 feet in footprint, respectively, with the first and last of the hangars each estimated at a $1,250,000 cost. In a second late 1940s master plan, *Pictograph of Wright-Patterson Air Force Base* of 1948, Air Installations illustrated 10 hangars paralleling the VVHB runway at Patterson Field. The plan located the proposed hangars between Building 30206 and the new flightline. Of these, five were hangars for the VVHB (B-36)—laid out as two buildings side by side, in a triple and doubled configuration of individual hangar bays. Approximate dimensions of the hangar bay in the pictograph was 340 feet wide and 300 feet deep, with a 300-foot wide aircraft door 40 feet tall. The door additionally featured a tail opening 20 by 50 feet. Shown as an arched structure, the VVHB hangar was most likely the design of Anton Tedesko, as a direct follow-on to his work on Building 20004 at Wright Field and as the predecessor to his design for the thin-shell, reinforced concrete SAC B-36 hangar of May 1947. The Patterson Field hangars were slightly smaller than the hangars built for SAC at Rapid City (Ellsworth) and Limestone (Loring) Air Force Bases from Tedesko's 1947 design (with a footprint of 370 by 314 feet), although door configuration is identical. As in Building 20004, the five planned B-36 hangars for Area C at Patterson Field were immediately contiguous, separated by firewalls (see Plate 185). In the final design of May 1947 for SAC, the individual hangar bays were free-standing. At Limestone (Loring), SAC planned for multiple B-36 hangars much like at Patterson Field (also freestanding, rather than attached in multi-bay units). Whereas, Air Materiel Command had proposed five arched hangars for Patterson Field in 1948 in a follow-on to its preliminary plans for the B-36 the year before, in mid-1948, SAC intended to build 10 of Tedesko's thin-shell hangars for the B-36 at Limestone[37] (Plate 193).

At the time of the late 1940s master planning for Wright-Patterson Air Force Base, Anton Tedesko (as a member of Roberts & Schaefer) had designed three thin-shell hangars for the Air Corps at

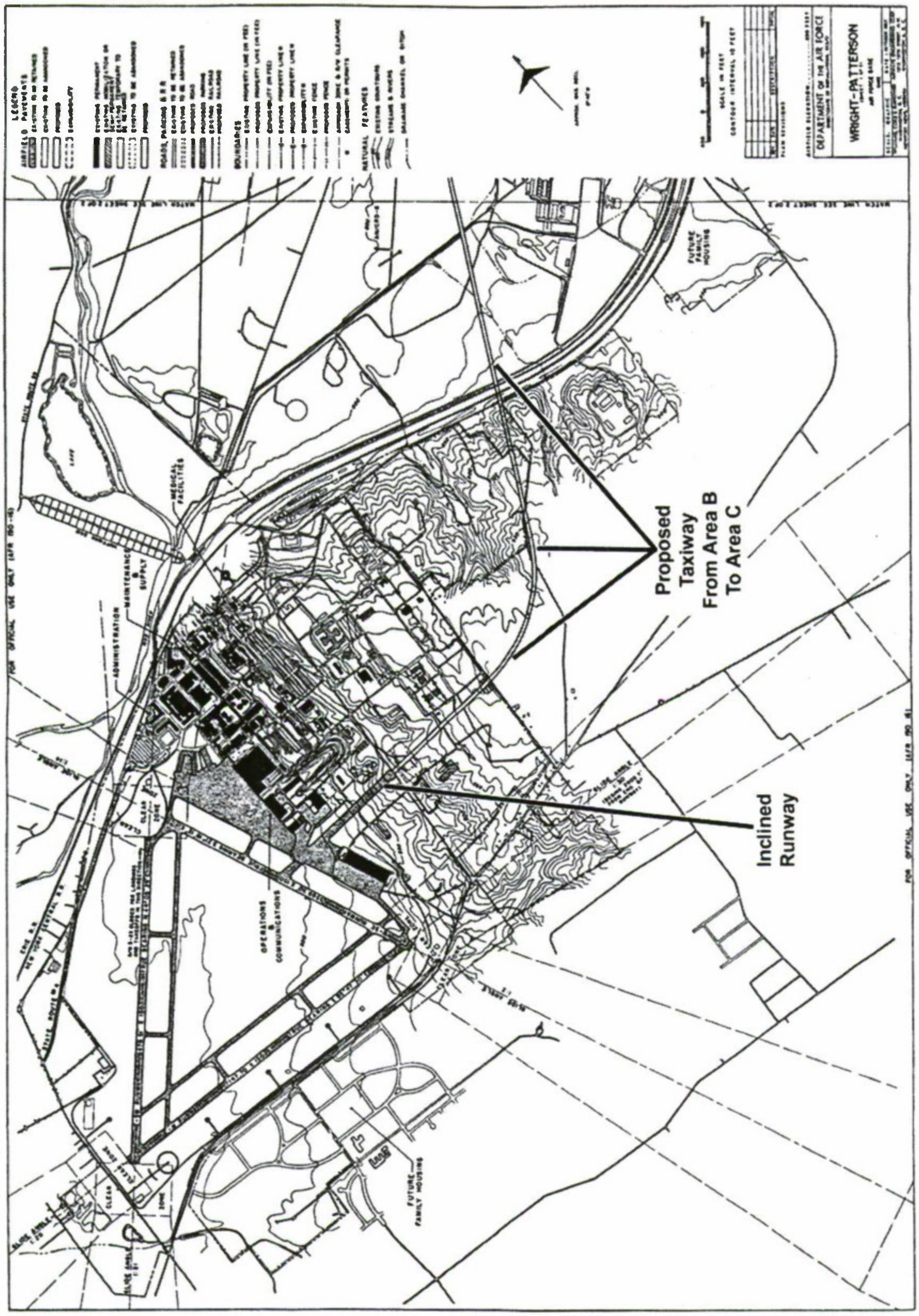

Plate 191: Directorate of Installations, Headquarters United States Air Force, Master Plan for Wright-Patterson Air Force Base, Sheet 1 ("Wright Field"), October 1957. Proposed "taxiway" connecting the inclined runway in Area B to a proposed parking apron in Area C, center. Annotations added. Collection of K.J. Weitze.

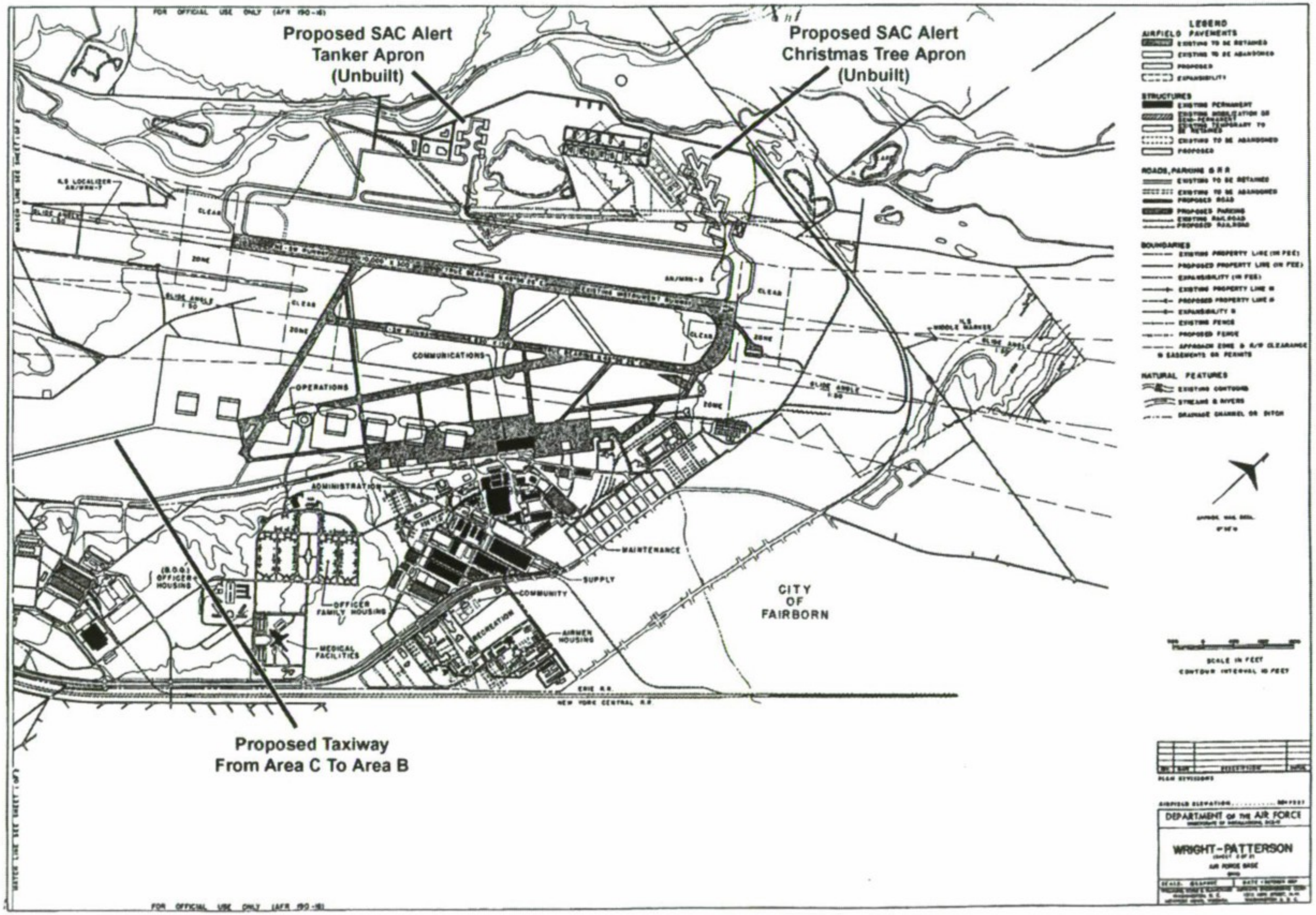

Plate 192: Directorate of Installations, Headquarters United States Air Force, Master Plan for Wright-Patterson Air Force Base, Sheet 2 ("Patterson Field"), October 1957. Proposed "taxiway" connecting a proposed parking apron in Area C to the inclined runway in Area B, center left. Proposed SAC alert aprons, upper center and right. The SAC Christmas tree apron was never constructed. Annotations added. Collection of K.J. Weitze.

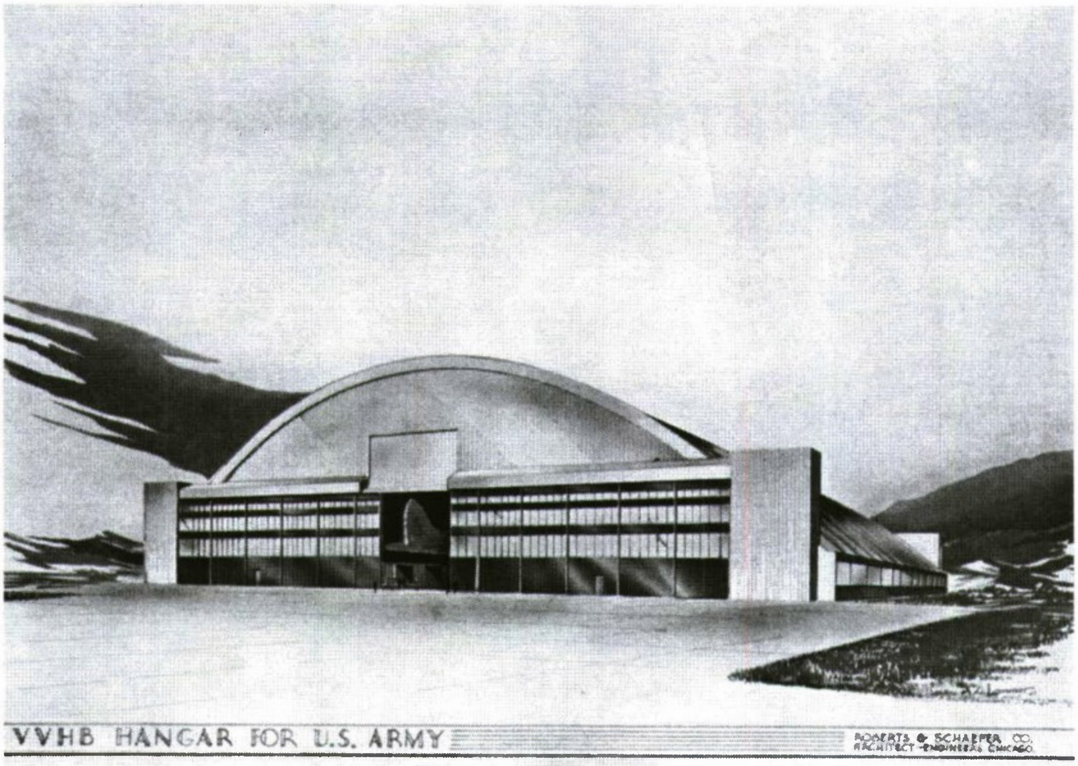

Plate 193: Roberts & Schaefer (Anton Tedesko). Presentation drawing for the SAC B-36 (VVHB) Hangar, 1947. Courtesy of the Civil Engineering Archives, Princeton University.

Borinquen Field (subsequently becoming Ramey Air Force Base) in Puerto Rico; two for the Army Air Forces at Andrews Field near Washington, D.C.; 16 for the Navy at Patuxent, San Diego (North Field), and Richmond, Virginia; and six (configured as two structures, Buildings 20004 and 20006) at Wright Field (see Plates 185 and 190). In 1945, ZD concrete construction had proved itself dramatically to the Army Air Forces. That year, an Army cargo plane had crashed through the door of one of the five bays of Building 20004 at Wright Field, exploding and setting fire to fully fueled aircraft parked inside. The 3.5-inch concrete shell sheathing the 160-foot clearspan space contained the fire completely—in a blaze of high-octane gasoline so hot that it fused glass. An intense updraft pulled pieces of asbestos cement siding from the end wall up into the air, subsequently dropping them on the thin-shell roof. After the fire, Air Materiel Command hired Roberts & Schaefer to conduct extensive tests and to repair the damaged hangar bay. Working with the United States Engineer Office and the Army Corps of Engineers testing laboratories in Cincinnati, as well as Headquarters Air Materiel Command and Headquarters Army Air Forces, Roberts & Schaefer placed 92,000 pounds of lead weights atop the hangar bay roof for a three-day period, taking deflection readings to check for plastic movement of the structure. Repairs ran to only $50,000, five percent of Building 20004's original million-dollar cost and a bargain for the accident.[38]

The engineering professional press showcased Building 20004 at Wright Field in the post-fire months, once again analyzing the merits of ZD technology (see Plate 185).[39] In 1945, too, Tedesko designed the first post-war, thin-shell hangar, a flight test hangar for General Electric in Schenectady, New York. Thin-shell structures dominated American radar and electronics test hangars of the 1941-1945 period. The partnership of Roberts & Schaefer in Chicago and Dykerhoff & Widmann in Germany had emphasized scientific testing of scale-models for thin-shell structures throughout the

1930s, with Roberts & Schaefer continuing this approach after the war into the 1950s both at the Fritz Engineering Laboratory at Lehigh University in Pennsylvania and a company test site in Harvey, Illinois, south of Chicago (see Volume I, Parts II and III). Roberts & Schaefer's methodology was a perfect complement to the research, development, testing, and evaluation mission within Air Materiel Command. In 1945, *Engineering News-Record*, one of two major American engineering journals, also carried articles and advertisements featuring interior and exterior views of Building 20005 at Wright Field, noting the generous light wells that the construction allowed in the shop roofs (see Plate 189).[40] As it unfolded during the late 1940s, thin-shell, concrete-arch hangars were the first built for civilian needs too. A competitor of Roberts & Schaefer—Ammann & Whitney of New York—designed a pair of two-bay hangars for Midway Field in Chicago in 1948 (for American and TWA). By 1949, Tedesko also was working in steel for the New York Port Authority. He was responsible for a hangar at Idlewild Airport that would become a model for a weights and balances hangar at Edwards Air Force Base during the middle 1950s (see Volume II, Chapter 3). While Air Materiel Command never built the two (triple and double) B-36 hangars on the flightline at Patterson Field, planning for the hangars demonstrated an enduring link between the Army Air Forces / Air Force and Anton Tedesko, one of the more remarkable engineers in the world at the time. A three-bay hangar for the bomber remained in active discussion into at least 1953 (see below),[41] with six generic maintenance hangars still forecast as late as autumn 1957 (see Plate 192).

While master planning went forward at Patterson Field for a VVHB runway and a cluster of B-36 hangars at Area C (the latter remaining unbuilt), another major project was one at Wright Field for a radar test laboratory. In the autumn of 1945, T-3, Engineering at Wright Field had established a committee to review existing R&D facilities "foreign and domestic" with an eye to determining what would be required to support an Air Engineering Development Center for Air Technical Service Command. The Wright Field study of 10 December 1945, *Proposed Air Engineering Development Center*, immediately predated Dr. von Karman's submittal of *Toward New Horizons*—the SAG study that followed von Karman's European tour of German scientific laboratories, personnel, and documents earlier in the year (see Volume I, Part III). T-3, Engineering projected an Air Engineering Development Center as a complex facility capable of testing aircraft and weapons components under multiple conditions, with a particular focus on experimentation at controlled subsonic to supersonic velocities. During late 1945 into 1949, the final location for an Air Engineering Development Center was under study. Air Materiel Command selected a pristine site southeast of Nashville, Tennessee, in November 1949, which became the AEDC. Simultaneously with the earliest iterations toward an Air Engineering Development Center in late 1945, the Royal Air Force (RAF) in Britain had also made suggestions toward a comprehensive aeronautical research center paralleling what unfolded as the AEDC. The RAF had called for the research center to be sited in Bedford, Massachusetts (an electronics R&D center that would ultimately evolve at Hanscom Air Force Base). T-3, Engineering at Wright Field, SAG in Washington, D.C., and the RAF had each evaluated the successful German centers during World War II (see Volume I, Part III). While Air Technical Service Command and its successor Air Materiel Command reviewed the possibilities, the commands also ran alternate scenarios as to what facilities would be needed where, dependent on the final location and design of the AEDC and on the developing network of other test centers.

The electronics mission, particularly radar testing, was very important to Air Technical Service Command in 1945, with the early augmentation of laboratories at Wright Field through acquisition of the Army's Watson Laboratories in New Jersey and the establishment of a Watson electronics and radar sub-unit at Cambridge in Boston (see Volume II, Chapters 5 and 12). The Cambridge Field Station of the Watson Laboratories absorbed many Boston personnel from MIT's Radiation Laboratory and the Radio Research Laboratory at Harvard, both contracted to the Office of Scientific Research and Development (OSRD) for electronics research during World War II and dissolved following the victories in Europe and Japan. The Electronics Subdivision was one of four within T-3,

Engineering at Wright Field and also supported five of the 15 T-3, Engineering laboratories (four electronics laboratories at Wright Field, and the fifth the Watson Laboratories in New Jersey with its Cambridge Field Station). As a follow-on to T-3, Engineering's December 1945 report *Proposed Air Engineering Development Center*, the Electronics Subdivision composed an 11-page document entitled *Facilities Required for the Five Year Program.* Although not yet completely verified, dating this document through internal references suggests its compilation occurred between March and July 1946. In *Facilities Required*, the Electronics Subdivision discussed alternate plans for top-priority facilities, relative to a juggling of which subinstallations Air Materiel Command would soon control—from Eglin Field and other Florida stations, to personnel units at Olmsted Field in Pennsylvania, Rome Field in New York, a cluster of Army installations in New Jersey and surrounding Boston, and selected experimental sites associated with the Watson Laboratories on the Atlantic Coast (including one at Oakhurst, Maryland). Each of the scenarios factored in combinations of potentially acquired research, development, testing, and evaluation centers, with and without the building of an Air Engineering Development Center. Within these situational previews, the Electronics Subdivision called out specific existing and new buildings for Wright Field.[42]

World War II radio and radar electronics structures discussed in *Facilities Required* were Building 20028, an aircraft radio laboratory constructed into a hillside in 1942 to test radio components in simulated environmental, vibration, noise, acceleration, shock, and other conditions;[43] 151,000 square feet of space in use within the headquarters building for Wright Field (Building 20125); and, the Signal Corps hangar (Building 20006) and its attachments. The Electronics Subdivision also provided scenarios for partial continued use or major renovation for Buildings 20011, 20014, and 20016 (administrative and laboratory structures from 1927-1943), dependent upon all other factors. Most noteworthy in this planning of early 1946, however, was a suggestion for two buildings:

- a "specially constructed building, with minimum metal used in construction, to be located in [an] area relatively free from electrical 'noise' and interference" (what would become Building 20821 of 1946-1948), and
- a "new Radio and Radar Building of permanent construction furnishing approximately 250,000 square feet, to be built in the vicinity of Building 125...to house Electronic Subdivision Headquarters" (Building 20433 of 1952-1953).[44]

The first of these two structures, further referenced in *Facilities Required* as the "Radar Hangar," was the single building that Electronic Subdivision insisted be commissioned for Wright Field in the near term, describing it in some detail and indicating that "immediate construction [was] needed whether [the] AEDC [was] built or not."

> This building...[is planned as]...100 x 200' with 75' clear floor space with 75' ceiling over the clear floor space...[and will]...be used for testing major ground radar and search equipment in systems with airborne components. Located north of the NYA [National Youth Administration] Area, Area B, this will provide a badly needed facility for combined air-ground system testing and in addition will house equipment now in the hill top area being vacated to provide space for the Air University.[45]

Air Materiel Command hired Hazelet & Erdal to design the "minimum-metal" structure discussed in the document of March-July 1946, the same Chicago-Cincinnati firm that had handled the Static Test Laboratory (Building 20065) of 1943-1944. Final drawings for the Radar Test Laboratory (Building 20821) are dated 31 July 1946, with preliminary design efforts likely partially collaborative between

Air Installations personnel of Air Materiel Command and the firm (see Volume I, Part III), and underway in the months before the submittal date.[46]

Often described as an "all-wood" structure, Building 20821 closely approximated the dimensions forecasted by the Electronics Subdivision, having a length of 200 feet, a span of 80 feet, and a height of 78 feet (75 feet, interior ceiling). Thirteen parabolic (also termed "catenary") laminated wooden arches defined the hangar-like structure. Each arch featured 19 laminations, and was just over nine inches deep and several feet thick (Plate 194).[47] While Building 20821 contained no metal nails or screws, instead relying on wooden pegs, the structure did incorporate what were termed "connectors"—fabricated from steel or sheet metal, and a key component of most glue-laminated beam structures of World War I forward. Building 20821 relied on a laminate and prefabrication process developed by Timber Structures, Incorporated, of Portland, Oregon, in about 1940. Timber Structures, Inc., had geared up for wartime production in late 1941 with a new manufacturing plant. Annotated construction photographs for Building 20821 of early 1947 list Timber Structures, Inc., as the primary subcontractor to the construction firm for the project, George W. Timmons of Columbus. While Hazelet & Erdal was responsible for the design and engineering of the Radar Test Laboratory—a prerequisite of which was a tall interior clearspan and radar invisibility to allow receipt of signals for components tested inside the laboratory (hence the nearly all-wood fabric)—Timber Structures, Inc., manufactured the individual laminated arches to the project's specifications. By 1947, Timber Structures, Inc., was well known for fabricating wood trusses, arches, and complete buildings that were shippable to location. Warehouses, storage facilities, shopping centers, halls, and schools went up in glue-laminated construction (also known as "glulam"), with Timber Structures, Inc., the leading components contractor. The light-weight wood members allowed tall clear heights and eliminated eaves, while a two-to-three part arch deliberately recalled the construction of barns. For Building 20821, workmen set up forms in Building 20006 for gluing together the laminated layers made by Timber Structures, Inc.

The Radar Test Laboratory resembled a scaled-down dirigible hangar (Plates 195-196). The design of Building 20821 is not fully researched here, but is tied to complex efforts of the Navy. During 1941-1943, the Navy had erected dirigible hangars at coastal locations in the continental United States. Seventeen of these were built as "all-wood" structures similar to the Radar Test Laboratory at Wright Field. The precursor structures for Building 20821 are these wooden dirigible hangars (of 1942), which had a steel predecessor (of 1941) and derived from the work of Goodyear in Akron, Ohio, to the northeast of Dayton. The earliest design efforts pertinent to Building 20821 were those of Dr. Karl Arnstein at Goodyear. Dr. Arnstein was born and educated in Prague, first working with renowned Swiss bridge engineer Dr. Joseph Melan. Between 1913 and 1924, Count von Zeppelin employed Arnstein at Luftschiffbau-Zeppelin to design and engineer aluminum dirigibles and their hangars. During World War I, Zeppelin manufactured airships for the German military, some of which were captured by the Allies at the end of the conflict. In 1924, the United States government brought Dr. Arnstein and a dozen German engineers to United States. The Treaty of Versailles had specified that the surviving German dirigibles and their hangars (almost all demountable) were reparations to be divided among Britain, France, Italy, and the United States.[48] With intentions very similar to those of Project Paperclip following World War II, the Navy Bureau of Aeronautics sponsored a Goodyear-Zeppelin enterprise in Akron as a subsidiary of the Goodyear Tire and Rubber Company. Dr. Arnstein headed the German coterie of engineers at Goodyear-Zeppelin. His assignment was to advance the development of dirigibles. Dr. Arnstein went on to design untethered balloons for stratospheric American military research, radomes, ejection capsules, high-strength laminated aircraft canopies, radar-equipped non-rigid airships (picket ships) for ADC's coastal patrolling as a part of the Distant Early Warning (DEW) and SAGE programs, and aluminum prefabricated housing. In 1929, Dr. Arnstein designed a 1,175-foot long steel dirigible hangar—

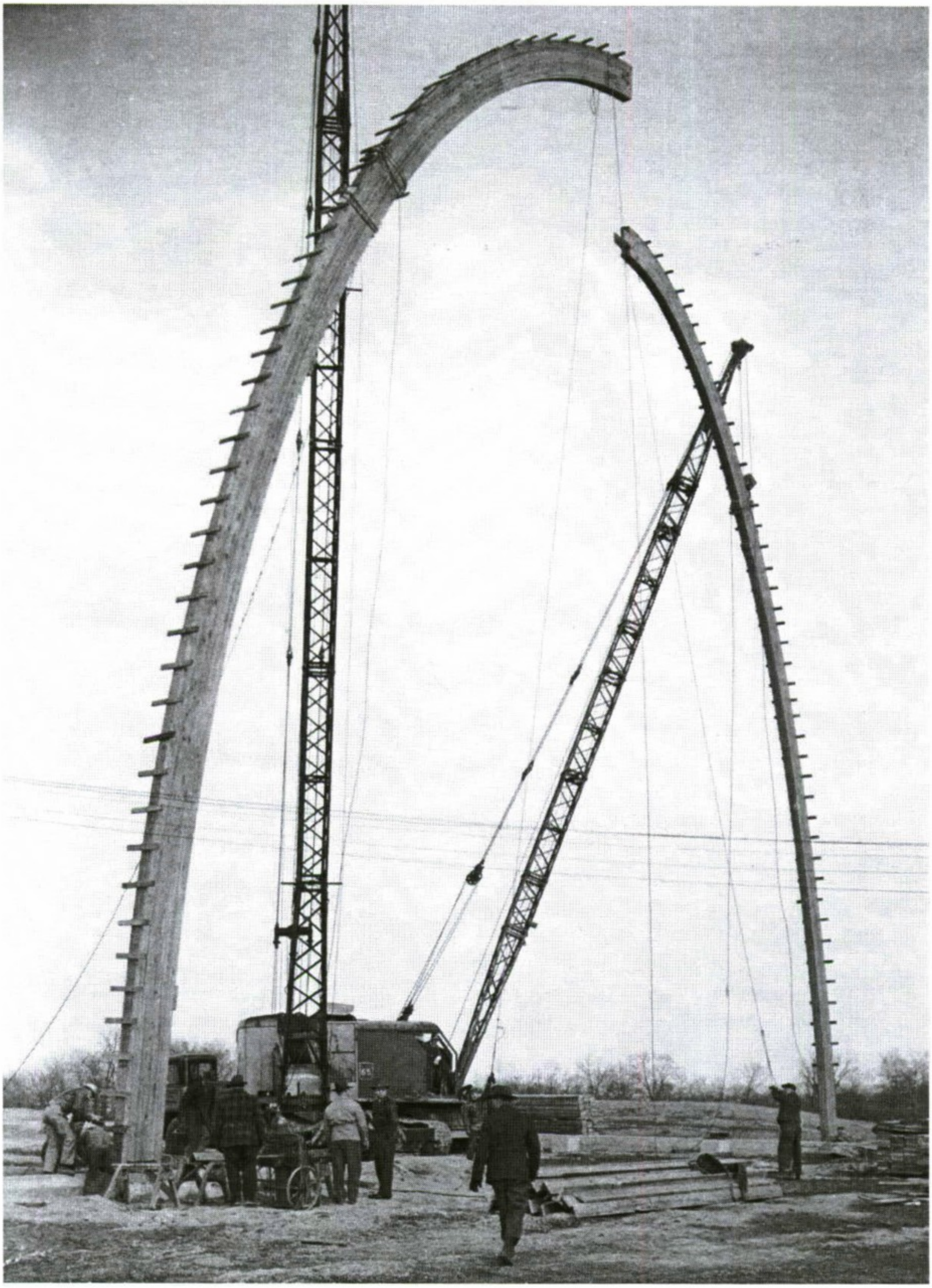

Plate 194: Timber Structures, Inc. Glue-laminated arches for the Radar Test Laboratory (Building 20821), Wright Field, 6 March 1947. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

Plate 195: Timber Structures, Inc. Thirteenth glue-laminated arch set in place for the Radar Test Laboratory (Building 20821), Wright Field, 18 March 1947. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

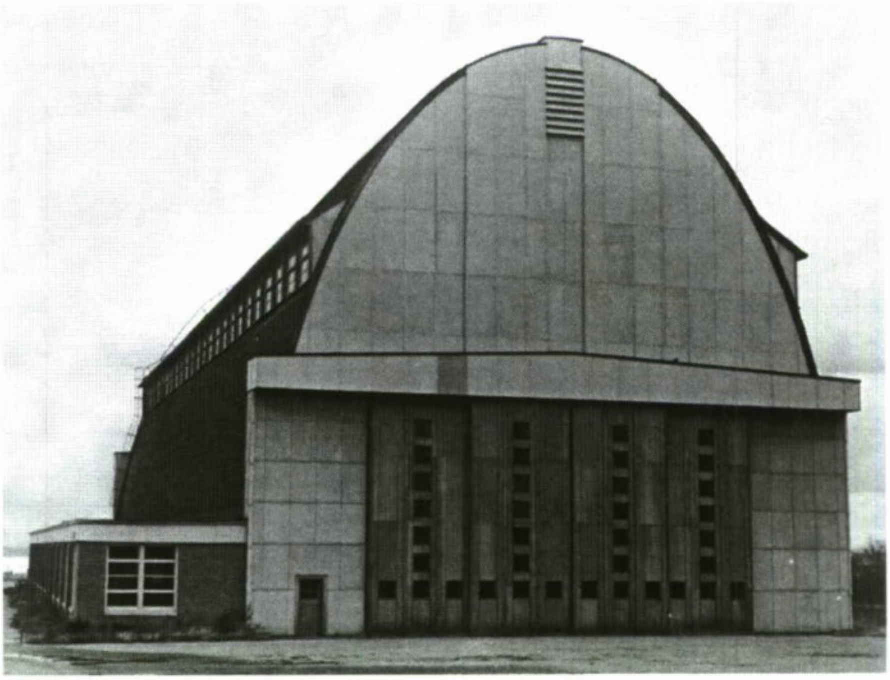

Plate 196: Hazelet & Erdal. Radar Test Laboratory (Building 20821), Wright-Patterson Air Force Base, view of 18 November 1949. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

325 feet wide, 198 feet high—for Goodyear at its manufacturing location adjacent to the Akron municipal airport. Goodyear used the air dock to build large rigid dirigibles for the Navy under contract. Dr. Arnstein relied on a semi-paraboloid shape for his dirigible hangar. As the 1920s closed, the Arstein Goodyear hangar (still extant in 2000) was the world's largest free-standing structure without interior supports.[49]

Within the aeronautical research community, developmental work toward lighter-than-air craft and supporting infrastructure advanced significantly during the 1930s and early 1940s. The Navy sustained two major installations with dirigibles, one at Lakehurst, New Jersey (in 1919), and a second at Moffett Field, California. The latter transferred to the Army Air Corps in the 1930s (who subsequently returned the property to the Navy, with an ultimate acquisition by NASA). Following Dr. Arstein's dirigible hangar in Akron, a second major steel dirigible hangar of about the same dimensions went up at Moffett Field in 1933. With the buildup for World War II, the Navy Bureau of Aeronautics increased its manufacture of dirigibles and embarked upon a program of hangars for dirigibles stationed on coastal alert. In 1941, Anton Tedesko prepared a design for an updated steel Navy dirigible hangar. The Navy Bureau of Yards and Docks took over the program in 1942. A steel shortage stimulated a redesign for the much-needed hangar by engineer Arsham Amirikian. Amirikian, an Armenian engineer educated in Constantinople and Germany, had immigrated to the United States in the early 1920s. By 1928, he was working for the Bureau of Yards and Docks and became its chief by World War II. Amirikian's all-wood dirigible hangar featured a catenary arch (eggshell in form). His hangars were 1,088 feet long, 297 feet wide (a 246-foot interior, with a 235-foot clearspan), and 178 feet tall (with a 140-foot rise above the concrete bents). Timber arches were trussed (not laminated). Timber Structures, Inc., of Portland, fabricated the lumber components of the hangars, marking each piece for streamlined construction on site. The process eliminated the Navy's need for field drawings. Dr. Arnstein and Amirikian had approached the problem of arch shape primarily through an analysis of predicted wind loads. (Dr. Arnstein and the Navy Bureau of Aeronautics had tested scale models for dirigible hangars in wind tunnels during the late 1920s.) Another innovation of the Navy's wooden dirigible hangar was its steel ring connector manufactured by the Teco Connector System and distributed through the Timber Engineering Company of Washington, D.C. The ring connector increased the strength of the timber joints by spreading the load more equally over the cross section of the wood. The Timber Engineering Company established a distributorship nationwide after autumn 1941, and by 1948 had developed a range of metal connectors, including sheet metal anchors, and worked together with Timber Structures, Inc.[50] These steel and sheet metal components were small, placed on inside faces where wood members joined. The hidden connectors did not interfere with radar transmission.

The long program of careful engineering for dirigible hangars, beginning with Arstein's efforts for the Navy Bureau of Aeronautics in Akron, and culminating in Amirikian's internationally recognized all-wood dirigible hangars of World War II, set in place everything that was required to design the Radar Test Laboratory of 1946-1949 at Wright Field. The similar goals of the Navy Bureau of Aeronautics and Air Materiel Command also assured overlapping interests, as did continued work on radar by Goodyear for ARDC in its Akron facilities during the early Cold War (see Volume II, Chapter 12). (In 1951, ARDC superceded the R&D half of the former Air Materiel Command.) Very likely, even the clusters of German expatriate engineers working for the Navy in Akron and for the Air Force at Wright-Patterson contributed to the final design for Building 20821. *Civil Engineering*, the complementary American professional journal to *Engineering News-Record*, showcased the Radar Test Laboratory at Wright-Patterson in mid-1948, noting the success of its high laminated arches and the quality of its interior test space—the latter enhanced through a radiant heating system that kept temperature differentials very small between the floor and the ceiling, "as low as 1 or 2 deg."[51] The "all-wood" construction of Building 20821, achieved through the use of the hidden ring connectors, also foreshadowed the very large, wooden Electromagnetic Pulse (EMP) test structure at Kirtland of

the late 1960s (see Volume II, Chapter 8). Not only did an all-wood fabric allow non-interference with radar signals, it also made possible EMP testing—for identical reasons.

In 1953, ARDC added an anechoic chamber inside Building 20821, designed and constructed through the direction of the command's avionics engineer William Bahret (Plate 197). Mr. Bahret used polystyrene foam cones to sheath the sides of the chamber to establish a controlled area that absorbed radar signals rather than allowing their return. The anechoic chamber in Building 20821 was among the first of many such sophisticated test facilities for the Air Force. (The earliest precursor of the true anechoic chamber known to the author was a "free field" sound room erected at the Radio Corporation of America [RCA] Laboratories at Princeton, New Jersey, in 1943. RCA's test facility was three stories high, 36 by 48 feet in dimension, completely sound-isolated and sound-deadened "so that no echoes, reflections or extraneous sounds of any kind could be heard within."[52]) The anechoic chamber in Building 20821 permitted the study of radar signatures to develop stealth aircraft and to design decoys, missiles and satellites with distinctive radar cross section (RCS) appearances.[53] In 1953, ARDC also possessed an anechoic room in one of seven buildings at Wright-Patterson used by the Aero Medical Research Laboratory. Personnel employed the room to study the effects of intense sound on human and animal subjects. ARDC achieved this "quiet room" by lining inside

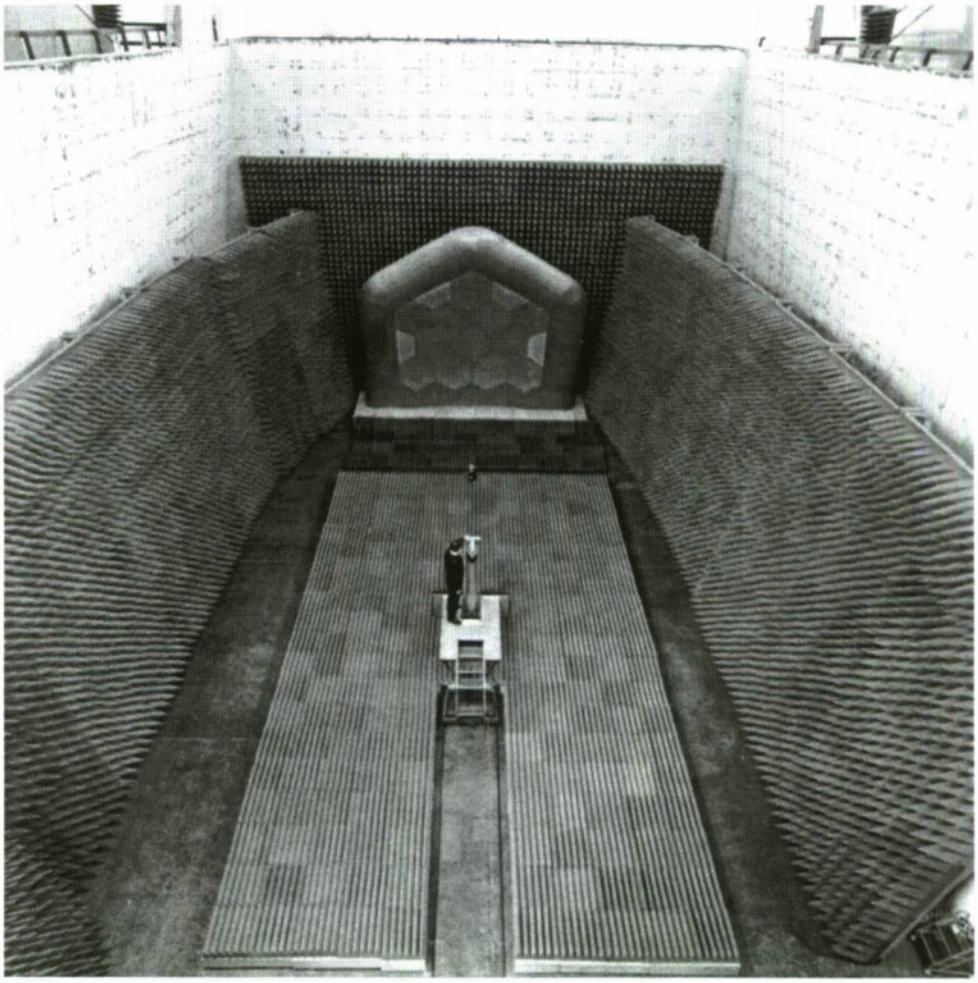

Plate 197: Anechoic Chamber, Radar Test Laboratory (Building 20821), Wright-Patterson Air Force Base, 28 November 1988. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

walls with 1.5 feet of Fiberglas, "wedges one foot high and eight inches square on the base."[54] During Fiscal Year (FY) 1954, ARDC additionally included a bioacoustics research structure in its planning (Building 20441), with the facility operational by autumn 1957. The new aeromedical building featured an anechoic chamber, 30 by 30 feet, to "simulate sound propagation in free space." ARDC built the second aeromedical quiet room to study "general criteria pertaining to effects of exposure to noise, reduction or control of noise, and protection against noise hazards."[55]

By the close of 1947, Air Materiel Command's research, development, testing, and evaluation program concentrated on nine defined "major fields:"[56]

- aircraft design,
- guided missiles,
- aircraft and guided missiles propulsion,
- electronics,
- meteorology and climatology,
- aviation medicine,
- armament,
- winterization, and
- atomic energy.

Within these categories, climate study had a special urgency due to world conditions and to "the probable locale of future hostilities." In addition to achieving aircraft and weapons performance in extremes of cold and heat, wet and dry, the command also initiated efforts toward "all-weather" flying. Implied was not only the need for improved aircraft capabilities and pilot skill, but also steps toward an air traffic control system "capable of giving ground personnel control of all aircraft movements in the air," and the development of pilotless aircraft that would largely be able to fly themselves in the decades ahead.[57] Air Materiel Command ran a weekly night flight between Clinton County Field in Wilmington, Ohio, southeast of Wright-Patterson, and Andrews Field outside Washington, D.C., between August 1946 and mid-September 1948. Engineering personnel never canceled the Clinton County – Andrews flight for weather conditions. The Clinton County airfield was also one deliberately left in a theater-of-war configuration that employed only a steel landing-mat runway.[58] If flying weather was good, the pilots flew their aircraft from beneath a "cockpit hood" that completely obscured vision.[59] For Project Summit of July 1949, Air Materiel Command personnel tested possible anti-icing systems for jet engines and engine parts atop Mount Washington in New Hampshire, verifying the applicability of a hot-air methodology.[60] By the end of the year, the command had approved about 450 aeronautical items for "Yellow Dot" tagging—markings added to indicate their compliance with extreme temperature requirements.[61] The other eight aeronautical research fields delineated in the late 1940s at Wright-Patterson were also starting complex programs (see Volume I, Part III, and all chapters of Volume II). At Wright Field, Air Materiel Command managed more than 2,000 research, development, testing, and evaluation projects at all times during 1947, beginning 922 new projects that year, finishing 540, and canceling or suspending 684 during these intense months.[62] In mid-October 1947, a directorate organization replaced the T-Staff system at Wright and Patterson Fields, the first of major organizational changes for the command and its successors during the Cold War.[63]

Examples of late 1940s endeavors at Wright-Patterson Air Force Base—the installation's designation in January 1948—varied from the nearly esoteric to the more broadly collaborative. Sometimes projects required new test infrastructure at the preexisting Wright and Patterson Fields (Areas A and B, and, Area C, respectively, with Areas A and C clustered around the Patterson Field runways—see Plate 184), while on other occasions existing infrastructure sufficed. One example of new buildings

and structures erected at the base supported Air Materiel Command's development of a full-scale supersonic propeller. Experimentation pointed to very thin blades with high rotational capabilities. Command personnel first tested scale models in wind tunnels, and contracted propeller companies ran studies at their own facilities.[64] Project Paperclip engineers with specific relevant background contributed to Air Materiel Command's progress. Friedrich von Doblhoff, the German inventor of the tip-jet powered rotor for helicopters, for instance, worked for the command at the base and on temporary duty assignment (TDY) in St. Louis for McDonnell Aircraft (see Volume I, Part III). During 1948-1949, Wright-Patterson took steps toward new test stands by commissioning a rotor fabrication shop (Building 20252) and planning for two outdoor test towers (helicopter and rotor) immediately east of Building 20020A (Plate 198).[65] Air Materiel Command completed construction of the outdoor rotor test tower in 1950 (Building 20250). The command erected a wholly new helicopter test tower (Building 20256) for the complex and also relocated a test stand of late World War II from inside Building 20020A to the site (constructing a fourth new "inside" propeller test stand in its place). By the middle 1950s, ARDC expanded the test area through construction of a gyroscopic propeller test stand to the further east (Building 20438).[66] At the other extreme of project types at Wright-Patterson, one collaborative effort of 1949 for the Photographic Laboratory on base involved transmitting aerial photographs from a reconnaissance aircraft to a ground station in Topeka, Kansas, and thence to facilities at Wright-Patterson, where intelligence staff could see the images within 20 minutes.[67]

While many of the projects underway through Air Materiel Command during the late 1940s were new for the Cold War era, or extended work begun during the last years of World War II, selected research, development, testing, and evaluation was particularly evocative of a clear distinction between past wars and those of the future. A scientific pursuit of air and space warfare itself defined many of the decades of the Cold War, eclipsed only in the later years by more complex geopolitical and economic factors. Within that pursuit, however, two related research arenas stand out as particular to the Cold War and of major importance within Air Materiel Command and its follow-ons ARDC / AFSC and AFLC. The first of these research concentrations was the sophisticated development of weapons of mass destruction, biochemical and nuclear; the second, that of a defensive network of warning for the continental United States. The Army Chemical Warfare Service and the NDRC, in conjunction with the Army Air Forces, had moved toward biological, chemical, and atomic weapons steadily during the 1942-1945 period. These special weapons projects linked forward to Air Materiel Command efforts of the late 1940s and early 1950s in Florida, New Mexico, and Utah (see Volume II, Chapters 4, 6, and 8). The atomic-biological-chemical (ABC) mission of the Air Force centered within Air Materiel Command by 1948, including:

- R&D directions for biological and chemical warheads (working with the Army);
- drone testing during atomic tests in the Marshall Islands of the Pacific;
- high-altitude agent-delivery testing;
- development of refrigerated vans as mobile igloos;[68]
- studies of nuclear weapons effects;
- long-range detection for nuclear weapons detonations;
- responsibilities for the design and engineering of nuclear weapons storage compounds; and,
- long-term development of protective, and subsequently hardened, construction (see Volume I, Part III).

The early infrastructure tied to the command's ABC mission at Wright Field is only partially known. In September 1946, drawings existed for three fungi laboratories, coupled with a temperature and humidity materials laboratory (Building 20281).[69] In 1948, Air Materiel Command also referred to chemical uses for a temporary building (possibly a quonset hut) and parts of the "old firing range in

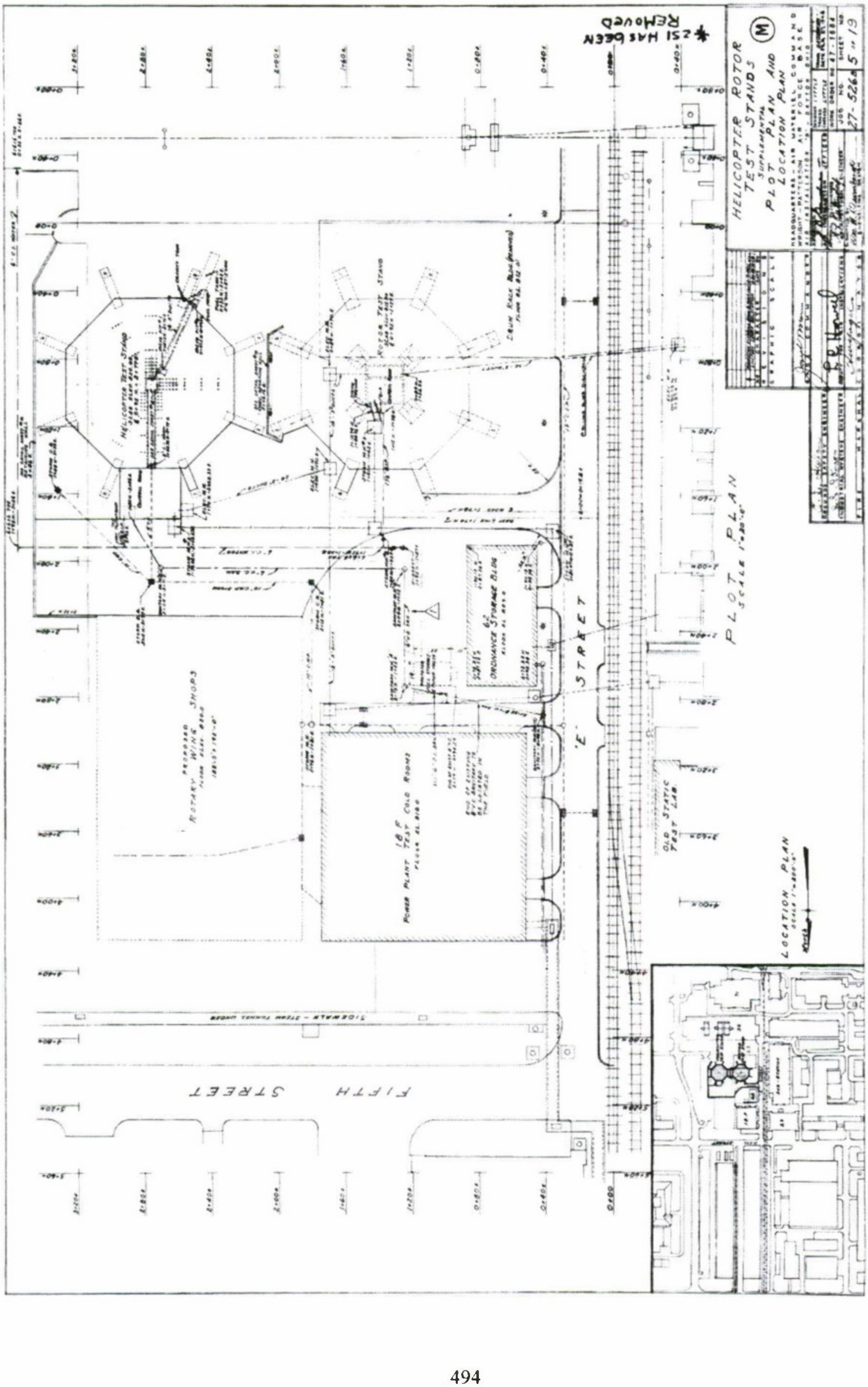

Plate 198: Helicopter Rotor Test Stands Plot Plan, Wright-Patterson Air Force Base, 27 February 1948. Courtesy of Civil Engineering, Wright-Patterson Air Force Base.

Area B" adjacent to the ammunition storage area, with additional plans for either new structures or modification of existing buildings. Air Materiel Command described these projects as the "Base Gas Chamber" and the "Chemical Training Area." The command intended to use the setup for chemical warfare training ("smokes, incendiaries, tear gas"), testing of gas masks, decontamination exercises, field identification of gases, and determining procedures for biological and radiological defense. Air Materiel Command considered the training area to be safe. The nearest road was 50 yards away and personnel aired out the facilities after tests. The base planning board specifically addressed the potential problems associated with certain agents. Personnel were to be exposed to poisonous gases only for field identification exercises. Air Materiel Command / ARDC restricted test materials to "small tubes of gases detonated with a No. 8."[70] By 1951-1952, the Department of Defense had allocated responsibility for "the development of biological and chemical warfare" to the Army (with Air Force input for its munitions; see Volume I, Part III), but "the Wright Air Development Center [WADC] retained responsibility for the design of containers and other equipment peculiar to the Air Force."[71] For biological agents, the Weapons Systems Division of the WADC faced significant challenges in designing mechanisms for dispersal, and for the munition's safe and effective transportation.[72] Decontamination following an enemy strike on the United States with biological weapons was also under earnest consideration, with two conferences held by the Materials Laboratory in August 1952 and January 1953.[73] A biological-chemical warfare laboratory in Building 20244 (with an adjacent trailer) was operational in July 1954: personnel studied the acute and chronic toxicity of materials in aircraft and conducted research against biological, chemical, and radiological agents.[74]

A second research, development, testing, and evaluation area particular to the Cold War, establishing an effective defense network for the continental United States, was an equally complex endeavor at Wright-Patterson Air Force Base. From as early as mid-1946 and continuing into late 1948, civil engineers at Headquarters Air Materiel Command had the responsibility for developing the preliminary specifications for both the Air Defense Control Center (ADCC) and Air Defense Direction Center (ADDC)—structures complemented by the command's efforts for infrastructure across the supporting network of Aircraft Control and Warning (AC&W) radar stations. Contracting the design and engineering for the ADCC and ADDC to the Chicago firm of Holabird, Root & Burgee during 1948-1949, Air Materiel Command worked closely with the architectural-engineering firm, with ADC, and with the Army Corps of Engineers (who managed aspects of the contracting, but did not execute design). The resulting protective construction of the air defense command posts was among the first such endeavor of the Cold War, with construction of the 11 command posts (ADCCs) and their tiered ADDCs between late 1949 and 1952. While awaiting the next generation of air defense command-post infrastructure, that of SAGE, ADC decided to expand its 11 ADCCs to 16 during the middle 1950s. These final five ADCCs served as placeholders and were most often short-lived, active only until a regional SAGE center came on line (see Volume I, Parts III and IV). Wright-Patterson received an ADCC in 1954-1955. The ADC command post was responsible for the 58th Air Division (Defense) of the Eastern Air Defense Force.

The 58th Air Division (Defense) first established operations in three World War II, 700-series, buildings in the Sherwood Forest barracks section of Area A at Wright Field: Buildings 11419, 11420, and 11421. The Army originally erected the three buildings in 1944 as standard, concrete-block administration and supply structures, each 100 by 40 feet. Buildings 11419, 11420, and 11421 were part of a grouping of a dozen structures on site.[75] Reuse of existing infrastructure while an ADCC was under construction was common for the air defense network. At the beginning of the program, ADC emphasized achieving operational capability. The command changed geographic boundaries for its individual air defense divisions throughout the 1950s (see Volume I, Part IV). Modification of the World War II buildings dated to October 1954. Drawings for the permanent ADCC followed in December. As a tenant on Wright-Patterson, ADC erected the ADCC, Building

11455, with a single small support structure, Building 11456 (likely a power substation). Typically, Air Division (Defense) command posts included an administration building and a power plant to support the ADCC, and in some instances also grouping an AC&W radar station (with an ADDC) at the same location (for example, at McChord and Tinker Air Force Bases, in Washington and Oklahoma, respectively). While all ADCCs uniformly used the October 1949 designs of Holabird, Root & Burgee for a Type 4 Operations Building, the final five ADCCs of post-1954—including that at Wright-Patterson—omitted the features for defense against biological, chemical, and radiological attack. The mid-decade streamlining of the windowless buildings included removal of the distinctive venting tower (roof air intake), chemical filter banks and their framing, outer- and inner-lock rooms, decontamination showers, fixed window louvers, gasproof clothing chute, gasproof doors, disinfector, baffle plate for the pressure relief valve, and other airlock details (see Volume I, Plates 78-79, 81-82, and 84).[76] Rationale for this change is unresearched, but is likely due to the awareness that SAGE was scheduled to replace these command posts and most would take on a different, sometimes administrative, mission.

The ADCC for the 58th Air Division (Defense) was the first erected of the stopgap five, with the others built at Andrews (Maryland), Truax (Wisconsin), Geiger (Washington), and Richards-Gebaur (Kansas) Air Force Bases. The ADCC at Truax, in Madison, literally went up adjacent to, and simultaneously with, SAGE Combat and Direction Centers on site. The transitional nature of these late ADCCs also seems to have encouraged their substantial renovation in later years, with those at Wright-Patterson, Andrews, and Truax verified as extremely modified[77] (see Volume I, Part IV). Of some note, Wright-Patterson added a Cable Repeater and Radio Relay Building (11457), also of windowless type and related communications function, adjacent to the ADCC in 1965-1966.[78] The 58th Air Division (Defense) functioned at the base for just over three years, between late 1955 and the beginning of 1959. At the initiation of its mission, the 58th Air Division (Defense) included 75 officers, 241 airmen, and 14 civilians, responsible for five AC&W radar squadrons located across its defense region of Ohio, Kentucky, Tennessee, and parts of Alabama, Georgia, Illinois, Indiana, Mississippi, North Carolina, Virginia, and West Virginia. The sector for the 58th Air Division (Defense) derived from parts of the preexisting 30th Air Division (Defense) centered at Willow Run, Michigan (southwest of Detroit), and the 35th Air Division (Defense), with headquarters at Dobbins Air Force Base in Marietta, Georgia. Also under control of the ADCC at Wright-Patterson were the alert fighter-interceptor squadrons for the region: the 355th Fighter Group and the 56th FIS (Wright-Patterson), the 87th FIS (Lockbourne), and the 319th FIS (Bunker Hill Air Force Base, Indiana). The command post additionally managed antiaircraft squadrons and the 4717th Ground Observer Squadron (the latter concurrently active at Wright-Patterson).[79] The assigned AC&W squadrons in March 1956 were the 663rd (Lake City Air Force Station, Tennessee), the 664th (Bellefontaine Air Force Station, Ohio), the 704th (Carmi, Illinois), the 782nd (Rockville Air Force Station, Illinois), the 783rd (Guthrie Air Force Station, West Virginia), the 784th (Fort Knox, Kentucky), the 799th (temporarily at Wright-Patterson, and then moved to Joelton, Tennessee), the 809th (Owingsville, Kentucky), and the 867th (Flintstone Air Force Station, Tennessee).[80] The AC&W station at Bellefontaine, to the northeast of Dayton, was a permanent installation for the sustained air defense network, and one which the 4706th Air Defense Wing at O'Hare Air Force Base in Chicago reviewed in person during the second half of 1954. Wright-Patterson provided logistical and maintenance support for the AC&W radar stations within its jurisdiction, including responsibilities for changes suggested by the 4706th Air Defense Wing for Bellefontaine[81] (see Volume I, Plate 88).

The air defense mission was a very important early Cold War tenant activity at Wright-Patterson, not only due to the role of Headquarters Air Materiel Command in the design and engineering for air defense command posts nationwide and to the presence of an ADCC on base, but also due to the parallel role of the alert FIS network. In September 1949, the 97th Fighter Squadron occupied the western section of the Operations – Transport Squadron and Flight Test Hangar (Building 30206) and

the air freight terminal to the west.[82] By December 1950, the 97th Fighter Squadron had become a formal FIS, with representatives of the Eastern Air Defense Force meeting at Wright-Patterson to discuss construction projects for alert infrastructure during the first half of 1951.[83] By March 1951, the 97th FIS occupied seven World War II temporary structures, Buildings 1445-1451, in an area not far from that subsequently selected for the ADCC of 1954.[84] In April, ADC commissioned two versions of a standard FIS alert hangar, one designed by the New York firm of Strobel & Salzman and an economy model by Butler Manufacturing of Kansas City. By later in the year, two other versions were also available (one erected only in three instances and the other placed predominantly overseas). At Wright-Patterson, ADC looked at both the Strobel & Salzman and Butler options, ultimately choosing the demountable, bolted Butler hangar. In June 1951, grading was underway for an alert area configured at one end of the VVHB runway at Patterson Field (in Area C).[85]

The Butler alert hangar (Building 30152) went up in spring 1952, accompanied by a readiness crew dormitory (Building 30151—now demolished) and a readiness / maintenance hangar (Building 30153). By mid-1954, ADC added a Unit A rocket checkout and assembly structure designed by Weiskopf & Pickworth of New York adjacent to the maintenance hangar (Building 30147) (see Volume I, Part IV and Volume I, Plates 94-95). The erection of a Butler alert hangar during 1951-1952 usually indicated a priority air defense mission. ADC constructed the Butler hangar only 15 to 20 times. Butler hangars represent about 22 to 28 percent of the total FIS hangars built in the United States and overseas. The readiness / maintenance hangar at Wright-Patterson also strongly suggests a priority FIS mission and appears to have been one of a kind. Headquarters Air Materiel Command had the responsibility for testing an aluminum version of the standard Butler alert hangar (for possible deployment in Alaska and Arctic regions) during April-May 1951, with the test structure erected at a Butler plant in Galesburg, Illinois. The aluminum readiness / maintenance hangar may have represented a similar effort, with the structure designed by the Reliable Engineering Corporation using a prefabricated hangar manufactured by the International Derrick and Equipment Company (IDECO). IDECO was a division of the Dreisser Equipment Company of Columbus (with branches in Texas and California). *Engineering News-Record* featured its prefabricated superstructure for a two-bay steel hangar at the Pittsburgh, Pennsylvania, airport in early 1954—soon after completion of the aluminum IDECO hangar at Wright-Patterson (see Volume I, Plate 95).[86] Personnel erected Building 30153 in only three months.

At Wright-Patterson, ADC planned for a more expanded fighter alert mission simultaneously with its construction of the ADCC for the 58th Air Division (Defense) (see Volume I, Part IV). In August 1955, the 97th FIS transitioned to the 56th FIS. By spring 1956, ADC discussed intentions to increase the FIS at the base to eight alert aircraft (a double squadron). While this situation also occurred at other installations in the continental United States between 1954 and 1956, it was rare. Sometimes ADC augmented an original Butler hangar with four pockets of the standard Strobel & Salzman structure (as at New Castle County Airport, Delaware, and Truax Air Force Base in Wisconsin), while in other instances the expansion continued to use Butler infrastructure (as at Griffiss Air Force Base in New York) (see Volume I, Plate 96). The 56th FIS at Wright-Patterson had been equipped with F-86Ds that carried folding-fin air-to-air rockets (FFARs). In early 1956, the base prepared for the F-89J and its weapon, the nuclear-tipped MB-1 Genie (also known as the Hi-Card and Ding Dong). ADC discussed adding four segregated multicubicle igloos and a checkout / assembly building, and planned to expand the existing munitions storage facility (Building 30147) through a Unit B checkout and storage structure. The command also intended to erect a cluster of four aircraft shelters (an ADC augmentation at some northernmost bases during the later 1950s). The overall ADC project for Wright-Patterson was a large one, estimated at a cost of over $2,100,000.[87] The Air Force commissioned the Kansas City firm of Black & Veatch to design the storage and checkout structures for the MB-1 Genie.[88] (Black & Veatch had designed a range of nuclear weapons igloos from 1946 forward, primarily through Headquarters Air Materiel Command). ADC programmed 23

locations for storage of the MB-1 Genie, with buildout between mid-1956 and late 1958.[89] Plans for deployment of the nuclear-tipped MB-1 Genie to Wright-Patterson changed, however, as did those for the overall expansion of the ADC alert area. ADC retained the original four-pocket Butler hangar, without augmentation. The command did not acquire the MB-1 Genie at the base, although in the late 1950s Wright-Patterson did receive very similar Black & Veatch-designed igloos for the Hound Dog, a nuclear guided missile carried by B-52s. Of note, the fighter aircraft most often fitted for the MB-1 Genie, the F-89J and the F-101B, were longer planes. Receipt of the MB-1 Genie mission required alterations to the front and rear doors of Strobel & Salzman alert hangars, as well as full replacement of the doors for the Butler structures. Retention of the original flat-faced doors on the Butler alert hangar, as at Wright-Patterson, is extremely rare, and captures the appearance of ADC alert during the earliest Cold War years. The 56th FIS deactivated at Wright-Patterson in March 1960, possibly due to the arrival of SAC at the base in the late 1950s and the congestion created by two alert missions at the northeast end of the Patterson Field runway.

In April 1951 (with transitional events the preceding year) Air Materiel Command divided into a logistics command retaining the name Air Materiel Command and a research, development, testing, and evaluation command, ARDC. Headquarters Air Materiel Command remained at Wright-Patterson, while Headquarters ARDC stayed on base transitionally (subsumed beneath Air Materiel Command) until a shift to Baltimore in June (and in late 1958, to Andrews Air Force Base outside Washington, D.C.). For the Air Force research mission, Wright-Patterson hosted one of ARDC's test centers, the WADC, also established in April 1951. At first, the WADC managed the other R&D installations accruing within ARDC, but in June these achieved center status parallel with the WADC. Headquarters Air Materiel Command continued to manage the evolving system of AMAs and also sustained its role in civil engineering efforts for both the command and the Air Force at large (see Volume I, Parts II and III). Major warehousing projects included the Special AMC Warehouse of 1952 designed by L.P. Kooken (see Volume I, Part II and Volume II, Chapters 6, 7, 10, 11, 12, and 13). With the Fairfield Depot (within the later Area C at Patterson Field) closed six years earlier, Air Materiel Command did not erect a Special AMC Warehouse at Wright-Patterson proper, but did build one nearby in Dayton at the Gentile Depot (see Plate 186). Later in the decade, the command returned to long-barrel, thin-shell construction, hiring Roberts & Schaefer for a ribless warehouse complex at the Olmsted Air Force Base depot in Pennsylvania. Air Materiel Command intended to erect Tedesko's exceptional warehouse of 1957-1959 at more than one location, but as had been true for the SAC B-36 hangars of 1947, construction went forward only in the single instance (see Volume I, Part II). Very unusual depot storage included igloos and checkout structures for atomic, and then thermonuclear, weapons. Headquarters Air Materiel Command at Wright-Patterson contracted with Black & Veatch for such compounds worldwide, including 13 in the continental United States. The program had gotten underway in the late 1940s, with buildout predominantly during the first half of the 1950s. Headquarters Air Materiel Command also trained personnel for the management of these special storage areas, with the 3079th Aviation Depot Wing at Wright-Patterson in charge of the numbered Aviation Depot Squadrons across the country from mid-decade until late 1962. (SAC took over management of the nuclear storage compounds thereafter) (see Volume I, Part II and Volume II, Chapters 7 and 8).

Air Force research, development, testing, and evaluation responsibilities for nuclear munitions of the early Cold War years (initially through Special Weapons Command and then through the Air Force Special Weapons Center under ARDC) included

> the support of atomic weapons tests, both military and by the Atomic Energy Commission; operational suitability testing of atomic weapons; and, at the request of the Wright Air Development Center, development testing of handling, suspension, and release equipment

> for atomic bombs. ...[R]esponsibilities to the Atomic Energy Commission consisted of support during atomic tests, including the bomb dropping and cloud sampling, and development testing of non-nuclear components, including the bomb case and bomb fuzing.[90]

The onset of the Korean War, too, coincided with the formal creation of ARDC, adding an immediate impetus for specific research, development, testing, and evaluation projects to the broader needs of the unfolding Cold War and the growth of a modern United States Air Force. The Korean War stimulated research toward improved jet aircraft and continued pilot training, both in reaction to the significantly faster, swept-wing MiG (Mikoyan Gurevich) -15 Soviet fighter planes supplied to North Korean forces. ARDC's test centers, as well as the laboratories of the WADC, contributed to the all-jet era ahead through:

- engine advancements;
- airframe engineering (focused on new hardening agents for steel alloys and experimentation with bonding adhesives);
- further refinement of swept-wing design (immediately after the war, for the B-47 and B-52 bombers, and the F (fighter) -89 and the Century Series);
- coordination of aircraft and runway design (focused on multi-wheel landing gear and flotation tires for very heavy planes);[91] and,
- testing of all-weather, high-altitude, and supersonic flight vehicles.

The conflict also necessitated:

- improved cargo transport (including first-time aerial refueling capabilities);
- reconnaissance and intelligence reporting (especially efforts toward improved night photography and infrared detection);
- aeromedical evacuation;
- search-and-rescue;
- better survival aids; and,
- in-field hospitals.

The hospitals developed and tested by ARDC during the Korean War evolved into full-scale prefabricated, shippable buildings during the Vietnam War 15 years in the future. Other achievements, such as radar-controlled bombing, improved strategic strikes in unfamiliar territory under cultural and climatically new conditions. North Korean winters demanded a heightening of functionality for aircraft, weapons, supplies, and military personnel under subzero circumstances, all of which had been predicted during World War II. During early 1951, the Aero Medical Research Laboratory at Wright-Patterson tested an "all-purpose, all-climatic ration" in a ten-day march by 40 men at Ladd Air Force Base in Alaska toward improvement of Arctic survival kits. The laboratory additionally ran a clothing program, experimenting for appropriate substitutes for scarce wool, leather, and furs.[92]

Representative of the complexities of the new research, development, testing, and evaluation stimulated through the Korean War, and yet pertinent to the Soviet-American Cold War more generally, was the Aircraft Radiation Laboratory's work toward infrared detection. The WADC hosted a conference at Wright-Patterson during late April 1952 on the subject, noting the efforts of its laboratories for the application of infrared to "reconnaissance, mapping, interception, fire control, search and detection, bombing, star-tracking, and missile guidance." Applicability to Korea and the Soviet Union was quite specific, including unanticipated challenges.

> [W]here enemy vehicles moved after nightfall and hid during the day, such [infrared] scanners would be able to pick up and pinpoint darkened convoys at night, and to discover the daylight hiding place of each truck, so long as the truck engine or exhaust continued to emit heat radiation. Tests in the early part of 1952 revealed that detection of trucks was possible at ranges in excess of four miles. The possibility of using infrared to locate and attack antiaircraft artillery firing on bombers in the Korean theater seemed a possible antidote for the current high loss rate.
>
> One handicap which existent infrared devices had not been able to overcome was the difference in the construction of Russian and American tanks. The Russians, using water-cooled diesel engines and well-concealed exhausts, had effectively, though probably accidentally, negated the usefulness of infrared as a tank detection device. American tanks, with air-cooled gasoline engines and visible exhausts, seemed almost intentionally designed for ready infrared detection. The center [WADC] concluded...that 'seekers intended for use against Russian tanks must have considerably greater sensitivity than is required for the detection of American tanks.'[93]

During 1951-1952, too, the WADC faced both facilities and manpower shortages, partly due to the general gearing up for R&D within ARDC and partly resultant from the Korean War effort. With formation of the WADC in early 1951, the center included spatial assignments in 173 buildings at Wright-Patterson. In many cases, research, development, testing, and evaluation endeavors split between Air Materiel Command and ARDC, with both commands having personnel and projects in single buildings. The WADC historians cited Building 20011, an administrative structure from the late 1920s that headquartered the Army Air Corps Materiel Division at Wright Field, as a case in point: Air Materiel Command, the WADC, the Navy, and "foreign consultants" [Paperclippers] occupied the building. By the close of 1951, the WADC occupied parts of just under 200 buildings on base, with extensive new construction planned. Nearby, off-installation test stations reporting to the WADC included geographically separate units (GSUs) at Sand Hill, Sulphur Grove, Vandalia, and Jamestown.[94] In planning for 1951-1953 were 25 new buildings and structures for Wright-Patterson, as well as selected additions and modifications to existing infrastructure. In addition to predictable requirements were a compass test building, an aeromedical high-altitude research laboratory, a multiple aircraft tracking facility, and a radome test range. (ARDC likely handled its radome test range as GSUs built for the Rome Air Development Center [RADC] at Griffiss [see Volume II, Chapter 12].) Projected funding for the infrastructure was in excess of $14 million.[95] Until the Korean War ended in late July 1953, the manpower shortage remained a pronounced problem.[96] The Research and Development Directorate of Air Materiel Command (and subsequently, ARDC) addressed the engineer and research scientist shortage, in part, through a second recruitment of German aeronautical specialists, initiated in November 1950. Entitled Project 63, the recruitment involved the Air Technical Intelligence Center at Wright-Patterson. Project 63 moved slowly during 1951, but accelerated when a team of interviewers (including several Paperclippers) traveled to West Germany and Austria for two months between late February and late April 1952. Processing for Project 63 continued into 1954, with some recruitment extended into 1958. ARDC was not the only recipient of late "Paperclippers," but was among its heaviest benefactor (see Volume I, Part III).

The first few years of existence for the WADC, and for Cold War research, development, testing, and evaluation at Wright-Patterson, were critical in defining the decades ahead. In mid-August 1953, *Aviation Week* devoted a full-length issue to ARDC and its centers. The periodical characterized the

WADC as a $200-million research establishment, with 12 laboratories and flight testing facilities spread across 1,325 acres. By this date, contracts overseen by the WADC accounted for 87 percent of the center's total budget. Research, development, and test contracts involved 130 colleges and universities, as well as industry and nonprofit organizations. Headquarters for the WADC, along with the greatest concentration of its laboratories and test facilities, was in Area B (at the former Wright Field). In terms of personnel and equipment value, the WADC functioned as the largest single installation within ARDC (with the centers at Eglin and Patrick in Florida, and Edwards in Southern California, larger in acreage). By late 1953, Area C (at the former Patterson Field) was maturing as the location of the Directorate of Flight and All-Weather Testing and the Directorate of Support. Personnel in Area C employed the 10,000-foot long VVHB runway for WADC missions, responsible for maintaining and modifying 150 to 200 aircraft for special flight tests. The Aircraft Laboratory, within the Directorate of Laboratories, for example, featured six state-of-the-art wind tunnels, facilities used by personnel for testing at the WADC and by military contractors for aircraft in development.[97] The Aero Medical Research Laboratory, under the Directorate of Research, was another institution of basic importance to the WADC. Efforts of the aeromedical engineers and scientists at the center included a converter for liquid to gaseous oxygen (installed on the F-84 as standard), new anti-G suits, aluminum foil packs for crew inflight meals, and the development of Aeroplast for protective clothing.[98] A high-altitude chamber for aeromedical studies had been operational at Wright Field in 1943 (Building 20197), with a human centrifuge and a horizontal spin table functional in Building 20033 in 1948 and 1950.[99] Air Materiel Command also outfitted an airborne psychology lab in 1950—a modified C-47 transport aircraft—for testing human response to cockpit controls.[100]

Between 1953 and the end of the decade, facilities planned and added for the WADC at Wright-Patterson (and for use off site) were numerous. For the FY 1954 program, the center's projects included modifications of the Static Test Laboratory (Building 20065) for a high-temperature test chamber. Vitro Engineering (formerly, Kellex) of New York undertook the job in September 1957.[101] Anticipated costs for the facility were $7 million. The WADC also planned for a Precipitation Static Facility for FY 1954. The center anticipated new laboratories for electronics, photography, dynamic systems engineering, bioacoustic research, elastomer-plastics R&D, and metallurgy. With drawings completed in mid-1955, a multi-laboratory aeronautical research complex (Building 20450) included chemistry, engineering physics, modern physics, applied mathematics, metallurgy, mechanics, system dynamics, and fluid dynamics facilities.[102] Still on the list of 23 major facilities in the FY 1954 program was the VVHB hangar (at over $5.5 million by this date), although the hangar would remain unbuilt. Mid-to-late decade additions for the WADC also included specialized chambers for the Aerospace Medical Laboratory:

- a temperature-altitude chamber in Building 20029 (with a planned operational date of 1958);
- a vertical accelerator, deceleration tower, ejection tower, and equilibrium chairs in Building 20023 (1956–1959);
- an isolation chamber in Building 20033 (1956);
- a high-altitude test chamber in Building 20248 (1955); and,
- a bioacoustics research facility, Building 20441 (1955-1957).[103]

Approaching mid-decade, anticipated GSUs hosted multiple projects. The Mount Washington, New Hampshire, test center included a helicopter hangar and a high-speed icing Venturi. Perhaps most notable for FY 1954 was the listing of the Nuclear Propulsion Aircraft (NPA) flight test base at Arco, Idaho (planned at $14,506,000).[104] The Arco facility was a large Navy operation established in 1949, first known as the National Reactor Testing Station (NRTS) (in 2000, the Idaho National Engineering and Environmental Laboratory [INEEL]). The NRTS was responsible for the research, development, testing, and evaluation of naval and breeder reactors, including prototypes for submarines and aircraft

carriers.[105] The NPA flight test base continued to be listed for the WADC public works program for 1955-1956, with an expenditure of $13,593,000 anticipated for FY 1955 and $3,015,000 for FY 1956.[106] Another off-site WADC facility was a supersonic test track located on the Lower Smith Mesa between Hurricane and Rockville, Utah (Hurricane Mesa). Constructed in 1955, the track (also known as the Coleman Track after the name of its operating contractor, Coleman Engineering of Los Angeles) supported testing for ejection from high-speed aircraft. The Air Force Flight Test Center at Edwards Air Force Base later took over responsibility for the track (see Volume II, Chapter 3).[107]

Two major nuclear power projects were underway through the WADC in 1951. While the center had many nuclear physics projects underway for the Air Force, including efforts focused on low-level radiation phenomena, the physics of the elementary particle, the nuclear structure of reactions, and radioactive nuclide research, the WADC's work on nuclear reactor research and aircraft nuclear propulsion was the most prominent.[108] American scientists and engineers had considered the possibilities of nuclear-powered vehicles as early as the Manhattan Project of World War II. Immediately after the war, the American government set up the Nuclear Energy for the Propulsion of Aircraft (NEPA) program and established a contract for the development of an atomic-propulsion aircraft with the Fairchild Engine & Airframe Company. Studies went forward at Oak Ridge, Tennessee, between 1946 and 1951. Coincident with ARDC's independent status as a command in 1951, a new program replaced NEPA. Known as the Aircraft Nuclear Propulsion program (ANP, also referenced as NPA), it was a joint Atomic Energy Commission (AEC) and Air Force effort. For the ANP program, General Electric and the Pratt & Whitney Aircraft Division of United Aircraft Corporation researched nuclear-powered turbojet engines. Convair, the manufacturer of the B-36, built the Nuclear Test Aircraft (NTA)—a modified B-36 (the NB [special bomber] -36H) carrying a nuclear reactor, but flying under its own power. The Air Force intended that tests run with the NB-36H would be the initial step toward the design and engineering for two flying testbeds powered by atomic energy sources.

Air Force Plant (AFP) 4 at Carswell was the home installation of the NB-36H. The Nuclear Aerospace Research Facility (NARF) under the direction of the WADC and its follow-ons, Wright Air Development Division and Aeronautical Systems Division (ASD) within ARDC / AFSC, operated the NB-36H at AFP 4 (see Volume II, Chapter 15). The NB-36H made 47 test flights between 1955 and 1957. The aircraft featured a small, air-cooled nuclear reactor in its aft bomb bay, with substantial lead shielding for the flight crew compartment and around the reactor. Men removed the nuclear reactor from the NB-36H when the aircraft sat parked at Carswell, storing it in a special pit. The overall ANP program included work in other locations: General Electric engine research in Ohio and Idaho; Pratt & Whitney efforts at the Connecticut Aircraft Nuclear Engine Laboratory; and, Lockheed testing near Dawsonville, Georgia (AFP 67). President Kennedy formally canceled the ANP program in spring 1961, noting that 15 years and one billion dollars in funding had not resulted in a nuclear-powered plane ready for military use. The AEC and the Air Force had each contributed over $500 million during that period, with the Navy funding the ANP to $14 million as well.[109] ASD at Wright-Patterson transferred the NARF at AFP 4 to the Air Force Weapons Laboratory (AFWL) at Kirtland in mid-1963, and at a subsequent date, the AFWL tore down all buildings at the facility (see Volume II, Chapters 8 and 15).

The key ARDC facilities for the ANP test program were those at Carswell (later known as the NARF) and, as planned, a small nuclear reactor for engine tests at Wright-Patterson. The Wright-Patterson Planning Board commented at a meeting of April 1954 that the Ohio reactor was "required to provide nuclear radiations for materials and systems tests essential to the development of nuclear powered aircraft and / or missiles." The envisioned reactor was to be a "gas-tight, shielded steel tank immediately south of Bldg. 433." In support of the nuclear reactor, Air Installations at Wright-

Patterson also discussed a 12- by 12- by 12-foot addition to the west side of Building 20433, the radiological instrumentation laboratory of 1952-1953, to store "nuclear material to be used for test purposes"—calling this proposed structure the Gamma Radiation Facility.[110] In the second half of 1954, the Assistant Chief of Staff, Installations (civil engineering) at Headquarters Air Force initiated development of criteria for the ANP (at AFP 4 at Carswell), negotiating an architectural-engineering contract with Charles T. Main in Boston to carry forward formal design work for the facility.[111] In April 1956, the Los Angeles engineering firm of Ralph M. Parsons completed drawings for the nuclear reactor at Wright-Patterson,[112] as a part of the overall complex for the base entitled the Air Force Nuclear Engineering Test Facility (NETF). Ralph M. Parsons' track record for the Air Force and the Navy was distinguished by this date, with unusual and sensitive assignments. During 1948, Ralph M. Parsons had designed technical facilities at Los Alamos, complementing the work of Black & Veatch. In mid-1952, Air Materiel Command had hired the firm to study the feasibility of hot-agent facilities for testing biological agents (at Eglin) (see Volume II, Chapter 6). By the summer of 1956, Ralph M. Parsons had also designed the high-thrust rocket test station at Edwards, underground bulk fuel storage facilities for SAC worldwide, and multiple structures for NRTS in Idaho. Before taking on the design of the reactor at Wright-Patterson (Building 20470), Ralph M. Parsons was involved in both the Navy and Air Force nuclear-powered aircraft programs (see Volume II, Chapter 3).[113]

The Directorate of Research within the WADC at Wright-Patterson managed the NETF from 1956 forward. During 1956, selected individuals within the directorate attended a two-week course in "Nuclear Reactors and Radiation in Industry" held at the University of Michigan, while the WADC picked others to go to a one-year program at the School of Reactor Technology in Oak Ridge, Tennessee, to foreshorten the time required to make an engineer into a "reactor engineer." The NETF included Ralph M. Parsons' Engineering Test Reactor Building (ETRB), a High Level Radiation Building (HLRB), a Waste Storage and Treatment Plant (WSTP), and a Nuclear Engineering Laboratory Building (NELB). The Directorate of Research described the planned reactor as "a 10 megawatt light water moderated-and-cooled heterogeneous core reactor of the LITR-ORR [Low Intensity Test Reactor – Oak Ridge Research Reactor] type." Initial anticipated cost for the NEFT was $7.5 million. The WADC intended to build (and fund) the reactor in a first stage of construction and the other three subordinate structures in a second stage—pushed forward into FY 1958. Early efforts toward the project included cross-military contributions, certainly those of the Navy toward nuclear propulsion, but also those of the Army. In September 1956, Army research specialists completed a quarter-scale model of the NEFT reactor complex at the Ballistic Research Laboratories (BRL) at the Aberdeen Proving Ground in Maryland. The BRL tests were to "experimentally evaluate the effects of blasts on the reactor structure and safety shell from simulated nuclear power excursions of the potential predicted by the 'Borax' test data." BRL results were to go to Ralph M. Parsons to allow modification of the reactor containment structures as well as the building. In early 1957, the Air Force anticipated submitting a final hazards report on the reactor project to the AEC Advisory Committee on Reactor Safeguards. The Directorate of Research discussed one additional structure related to the NEFT, a 170-foot steel tower to be erected near the reactor "to measure and record localized atmospheric diffusion characteristics." The directorate wanted to establish "stack release rates of radioactive gases from the NEFT" by acquiring this data for a year before beginning full operations.[114]

Both the ANP program at AFP 4 at Carswell and the NEFT at Wright-Patterson faced multiple challenges and set-backs. Test flights for the NB-36H in Texas ended just as construction for the nuclear reactor at Wright-Patterson began, although the formal ANP program remained on the books. Public Laws 910 (of the 81st Congress) and 155 (of the 82nd Congress) had authorized the NEFT, with construction underway in October 1956. By the end of June 1959, the reactor was 71 percent completed, but had run into significant problems.

> It has now been determined that this facility cannot be checked out or placed in limited operation without the inclusion of an Environmental Control System and Material Handling System, estimated at a cost of $3.3 million. It has also been determined that an additional $2.3 million is required for Increment II consisting of high and low level radiation evaluation and liquid waste disposal which will complete the facility to obtain normal operation on a very austere basis.

To continue building the reactor necessitated that the Air Force ask for another $5.6 million from the Congressional Appropriation Committee.[115]

During 1956-1959, other Air Force nuclear power programs connected to the reactor at Wright-Patterson were also in progress, facing many of the same difficulties. In about mid-1956, the Air Force planned a nuclear power plant for Sparrevohn Air Force Station in Alaska for FY 1958. The Air Force patterned the Sparrevohn power plant after the Army's APPR (Army Package Power Reactor) -1 at Fort Belvoir. The AEC's Oak Ridge National Laboratory (ORNL) conceived the APPR-1 and the reactor became the first prototype project in the Army Nuclear Power Program of 1952. The APPR-1 was the "grandfather" for military nuclear reactors, and the progenitor for the reactor at Wright-Patterson (Building 20470). Personnel brought the APPR-1 to criticality on 8 April 1957 and the plant generated its initial kilowatt-hour of electricity one week later (Plate 199). Site selection at Fort Belvoir in Virginia during 1954 collocated the APPR-1 with the Army's Engineer Research and Development Laboratories on site. (The Air Force also maintained the United States Air Force Engineering Field Office at the Army's Engineer Research and Development Laboratories for joint Air Force – Army civil engineering projects.) Designed and engineered by the American Locomotive Company (later named ALCO Products), the APPR-1 was built to:

- prove the design of a military nuclear power plant;
- provide construction, operating, and cost data for planning similar plants in remote areas (specifically, at Arctic AC&W sites and Air Force Stations like Sparrevohn); and,
- serve as a facility for training Army, Navy, and Air Force crews to operate nuclear power plants (such as the reactor in planning at Wright-Patterson).[116]

The Air Force plant at Sparrevohn was to provide electric power and heat. At the same time, construction was stalling on the Connecticut Aircraft Nuclear Engine Laboratory (referenced by the Air Force as CANEL) for the ANP program. Funding of over $10.5 million was in abeyance due to program uncertainty.[117] In late December 1957, the Department of Defense deleted the anticipated nuclear power plant for Sparrevohn Air Force Station from both the Military Construction Program (MCP) for FY 1958 and FY 1959. For CANEL, funding allowed completion of the propulsion facility and test shop, with an occupancy date of July 1958—although all other plans for the test location stopped.[118] In early 1959, the Air Force and the AEC jointly initiated pursuit of yet another nuclear power plant project: construction and service testing of a "factory-assembled modular power plant at AC&W Station TM-201 [Sundance, Wyoming, near the South Dakota border]."[119] At the end of 1959, the reactor at Wright-Patterson was 85 percent completed, described as at a "logical cut-off point where the environmental control and material handling systems can be added if funds are released."[120]

In late December 1959, *Engineering News-Record* included an article on the nuclear reactor at Wright-Patterson—presenting the design challenges of the project. A 159-foot high steel shell, 83 feet in diameter, housed the reactor, encased in concrete for leak tightness. Fifty feet of the shell was below grade. Concrete pours for the reactor casing were particularly complicated.[121] Plans

moved forward to allow checkout of the reactor for contract compliance while waiting for Congressional funding for an Environmental Conditioning and Materials Handling System.[122] By mid-1961, ASD (a follow-on to the WADC) finished additional engineering studies, with the reactor still only 98 percent completed (Plate 200).[123] Earlier that spring, President Kennedy had canceled the ANP program which the reactor at Wright-Patterson was originally to support. In late 1961, ASD changed the mission of the still not-active reactor to "that of a university type research facility," with nearly $1.5 million allotted to conclude construction before the "performance of hot-check-out." Simultaneously, the Air Force and AEC completed construction of the nuclear reactor at the AC&W station in Wyoming, with shakedown testing for that facility to begin in January 1962.[124] The Sundance plant was a relative success, operating for 6,660 hours by the end of 1963 and powering the radar installation.[125] By December 1962, ASD referenced the nuclear reactor at Wright-Patterson as one of the facilities built for the Air Force Institute of Technology. New buildings for the institute had been in planning since 1954 and were a design of the Detroit firm Giffels & Rossetti (see Volume II, Chapter 11).[126] By mid-1964, the anticipated total cost to complete the NEFT at Wright-Patterson reached just under $13 million—up from the $7.5 million estimated back at the project's start in 1956. AEC's review directed changes and modifications for hazards. Such a long period elapsed between cold checkout and the still-ahead hot checkout, that costs would continue to climb.[127] As 1964 ended, a repeated cold checkout, as well as the hot checkout, remained undone. The Air Force projected that costs would hit $14 million. Waste disposal cells—part of the original design in 1956—were not yet built, although the contract was awarded. Construction for nuclear waste disposal was to occupy most of 1965, with cold and hot checks during the year. Ralph M. Parsons planned delivery of the reactor to the Air Force in mid-November—after a decade of starts, stops, and delays.[128] The Air Force did accept the NEFT for operational status in November 1965, but with deficiencies. Financial completion of the project moved ahead to autumn 1967, 21 years after the startup for the atomic-propulsion aircraft project, NEPA, for which the Air Force first envisioned Wright-Patterson's reactor. The Air Force Institute of Technology operated the NEFT for only a short period, closing the facility in 1971 due to budget cuts.[129]

While planning, construction, and modifications for the NEFT were in progress at Wright-Patterson during the late 1950s and early 1960s, the base also acquired a major SAC tenant mission. The 4043rd Strategic Wing (SAC) activated at Wright-Patterson in April 1959. The wing's compound was an accurate representation of SAC's cellular concept of alert. The 4043rd Strategic Wing was one of 65 SAC wings on alert in the continental United States and Puerto Rico (see Volume I, Part IV). The Air Force sited the SAC alert compound at Wright-Patterson across from existing ADC alert at the end of the Patterson Field VVHB runway in Area C. While both ADC and SAC sustained alert at single installations often enough, when this occurred at one end of a runway both spatial constraints and existing installation lands could mandate changes from the standard layout for one or both commands—particularly if either ADC or SAC also received nuclear munitions (the MB-1 Genie for ADC and the Hound Dog for SAC), as each necessitated segregated multicubicle storage areas. At Wright-Patterson, the 56th FIS deactivated in 1960, less than a year after activation of the 4043rd Strategic Wing. While the SAC alert crew quarters (the 70-man molehole, Building 34004) was in construction (see Volume I, Plate 104), the 4043rd Strategic Wing occupied the ready crew dormitory of ADC (Building 30151) (see Volume I, Plate 95) after becoming operational in July 1960. SAC alert facilities at Wright-Patterson included its molehole, operations and industrial buildings (Buildings 34010 and 34012) (see Volume I, Plate 105), a warehouse (Building 32014), supporting fuel systems and maintenance nose docks (Buildings 34020, 34022, 34024, 34026 and 34028), a Hound Dog / Quail service shop (Building 34042) (see Volume I, Plate 106), Hound Dog and Quail run-up shops (Buildings 34046 and 34044) (see Volume I, Plate 107), two multicubicle Hound Dog magazines (Buildings 34062 and 34064) (see Volume I, Plate 108), and a Hound Dog checkout and assembly building (also known as a surveillance and inspection structure) (Building 34066) (see Volume I, Plate 109).[130] In addition to these 14 main structures, the SAC

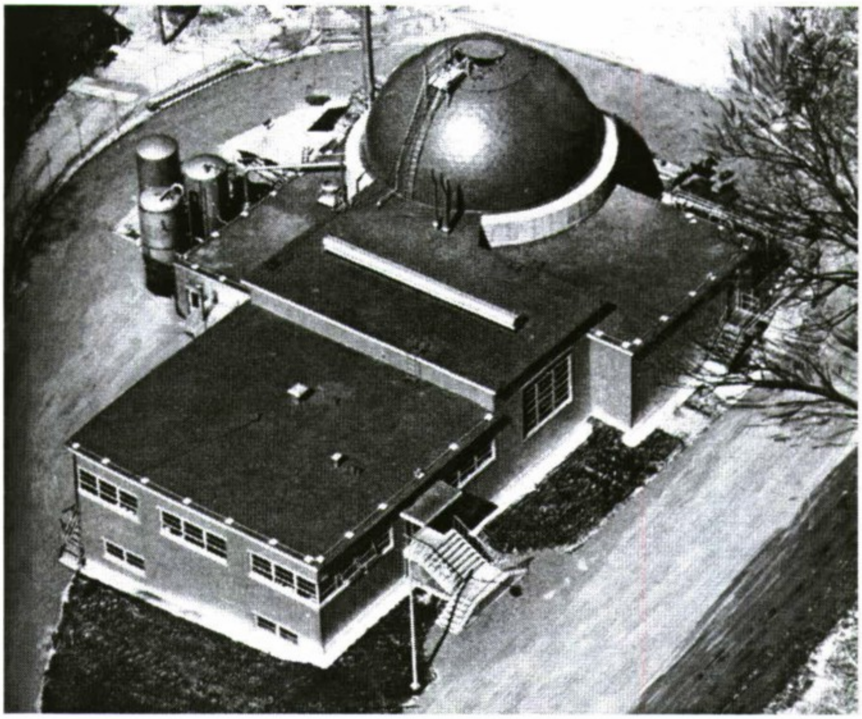

Plate 199: American Locomotive Company. Army Package Power Reactor (APPR) –1, Fort Belvoir, Virginia, 1954-1957. In *The Military Engineer*, November-December 1957.

Plate 200: Ralph M. Parsons. Air Force Nuclear Engineering Test Facility (Building 20470), Wright-Patterson Air Force Base, 1956-1965. Background, left to right: Buildings 20006, 20065, 20022, 20009, 20005, and 20001. Photograph of 17 April 1970. Courtesy of the History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

mini-installation in Area C at Wright-Patterson included another 10 buildings to support its mission on base.

Typically, where SAC was a tenant and maintained alert, its enclave followed a rigorous pattern. Of the 65 SAC alert groupings, all employed the standard design of April 1958 for the molehole (either 70-, 100- or 150-man) by the Omaha firm Leo A. Daly. Giffels & Rossetti of Detroit designed the cellular trio of operations, industrial, and warehouse buildings (in early 1959); Ganteaume & McMullen of Boston, the Hound Dog guided missile run-up and maintenance structures and those for its paired Quail decoy (also in early 1959); and, Black & Veatch of Kansas City, the Hound Dog multicubicle munitions igloos and checkout building (in mid-1958) (see Volume I, Part IV). SAC paired the nuclear-tipped Hound Dog (Guided Air Missile [GAM]-77) with the Quail (GAM-72) at only 14 of the 65 installations on alert (another 15 bases received the Hound Dog without the Quail, while no base had the Quail alone). Possession of the weapons pair denoted a SAC alert of high priority. At Wright-Patterson, due to constraints of Patterson Field, the 4043rd Strategic Wing did not possess the usual herringbone alert apron (Christmas tree), and instead operated from a generic rectangular apron (as did happen at selected installations). As late as October 1957, SAC planned for an eight-stub Christmas tree apron at the end of the Patterson Field runway opposite the FIS alert compound, and also planned for a five-stub, right-angled tanker alert apron centered along the runway at the rear of a rectangular parking area. Neither of these two alert aprons were built as originally configured. SAC shifted the rectangular apron closer to the alert end of the runway, deleted a Christmas tree altogether, and turned the tanker alert stubs to parallel the apron they accessed. The rectangular apron functioned as a parking area for the bombers on alert, while the secondary tanker alert apron accommodated fuel systems and maintenance nose docks. SAC's 1957 intentions for a pair of bomber and tanker aprons, however, was very unusual and very early, again emphasizing the importance of SAC's alert at Wright-Patterson (see Plate 192). The 34th Bombardment Squadron replaced the 4043rd Strategic Wing at Wright-Patterson in early 1963, with SAC leaving the base in autumn 1975 (see Volume I, Part IV).

During the 1960s and 1970s, Wright-Patterson continued to be the headquarters location for Air Materiel Command and its follow-on AFLC, while ARDC became AFSC (in 1961) and the WADC evolved as the Wright Air Development Division (in 1959) and subsequently as ASD (1961). Organizational changes for the laboratories also occurred (see Volume I, Part II). Systems acquisition shifted from Aeronautical Systems Center within Air Materiel Command to AFSC, simultaneously with Air Materiel Command's change to AFLC.[131] The Air Force industrial plants program transferred over to AFSC as a part of the reorganization for systems acquisition, although not all plants moved from AFLC to AFSC until about the middle 1970s (see Volume II, Chapter 15). The new ASD included the research, development, testing, and evaluation responsibilities formerly within the Wright Air Development Division and the procurement responsibilities absorbed from Aeronautical Systems Center. ASD continued its core flight and all-weather test mission, as well as associated maintenance and modification taskings. As of the late 1950s, personnel at Wright-Patterson also contributed toward R&D for space flight[132] (see Volume I, Part IV). From the early 1960s through the end of the Vietnam War in 1975, Wright-Patterson handled weapons and supporting systems research, development, testing, and evaluation appropriate to the conflict. The period also witnessed a rise in Air Force civil engineering efforts coordinated through Wright-Patterson (see Volume I, Part III, and Volume II, Chapters 4 and 8). Sophisticated civil engineering included:

- the design and testing of prefabricated, modular building units (dormitories, hospitals, and other cantonment-type structures) for theater-of-war situations;
- fast-fix solutions for damaged runways; and,
- a complex sequencing for protective aircraft shelters—the latter coupled with revetments in Southeast Asia, and elevated to nuclear-hardened structures for air bases in Europe.[133]

Tactical Air Command's (TAC's) Bare Base program maintained a project office at ASD at Wright-Patterson as of April 1966, to develop "a more adequate flyaway kit to support tactical operations."[134] AFSC and TAC conducted Bare Base testing, along with that for multiple prefabricated structures, at Eglin in Florida (see Volume II, Chapter 4). The protective aircraft shelters program involved the Air Force Special Weapons Center (and subsequently, the AFWL) at Kirtland in New Mexico, as well as testing on the ranges associated with Hill in Utah (see Volume II, Chapters 6 and 8). During the Vietnam War, AFLC concentrated on shipping materiel to Southeast Asia, along with appropriate aircraft overhaul throughout the conflict. AFLC also established Prime BEEF (Base Engineering Emergency Force): mobile civil engineering units coupled with those of Red Horse (Rapid Engineer Deployable Heavy Operations Repair Squadrons, Engineering) to meet construction needs during the war. Wright-Patterson's 2750th Air Base Wing provided 15 men for the first Prime BEEF unit in November 1965.[135]

Major new R&D facilities at Wright-Patterson during the 1960s included ones for advanced avionics. Under the WADC, the Directorate of Laboratories had split into the Directorate of Development and the Directorate of Research in late 1955, shifting several more times in the late 1950s to become a three-directorate organization (Systems Management, Systems Engineering, and Advanced Systems Technology). An Avionics Division had existed within the Directorate of Advanced Systems Technology under the Wright Air Development Division. With the evolution from ARDC to AFSC in 1961, line organization changed again. Four deputates replaced the former three directorates, although within ASD's Deputy of Technology the Avionics Division sustained its continuity. President Kennedy's desire to strengthen the in-house laboratories of the Department of Defense led to further restructurings by 1963. Avionics, as an example, became one of four major laboratories under the Deputy of Technology within Aeronautical Systems Division.[136] The Avionics Laboratory at Wright-Patterson of the 1960s and 1970s focused on research, development, testing, evaluation for electronic countermeasures, microelectronics, phased-array radars, radar warning systems, infrared sensors, and laser targeting.[137] In 1962, Yosh, Nakazawa & Associates of Chicago completed drawings for a modern avionics laboratory in Area B (Building 20620), a facility at Wright-Patterson strongly associated with state-of-the-art R&D in Air Force electronics.[138] Initial construction ran until 1967, with the 13-story twin towers the building's visually distinguished feature. Work toward reconnaissance, sensor, and navigational systems, as well as artificial intelligence, multiple important radars, stealth advancements, and electronic warfare technologies of the late Cold War, occurred in Building 20620. Known as the Electronic Warfare Research Facility, Building 20620 included an advanced anechoic chamber to test model aircraft against varied radio frequencies to improve stealth design.[139] In late 1964, Sanders & Thomas, Inc., of Philadelphia, finished their drawings for a second science laboratory for optics on the base, Building 20622.[140] Also operational in 1967, the optics laboratory contained the largest optical collimator internationally, fitted into the 10-story section of the laboratory. Personnel used the collimator to test the quality of photographic lenses for satellites and other surveillance devices. The collimator featured a 155-foot vacuum chamber, 85 feet underground and 75 feet above, with its lens at the base of the vertical structure.[141]

Following the end of the Vietnam War, Wright-Patterson continued as the headquarters location for AFLC and as a major center of activity for AFSC. The logistics command, AFLC, reorganized its materiel jurisdictions, the AMAs, into Air Logistic Centers (ALCs) in 1974 (see Volume I, Part II). Beginning in the late 1960s, too, AFLC seriously reduced the number of AMAs / ALCs, consolidating the supply, modification, and maintenance missions onto fewer installations. AFSC moved forward steadily in all preexisting R&D arenas, although once more revamped the personnel and resources of its laboratories at Wright-Patterson. In July 1975, four individual laboratories on base—those of Aero-Propulsion, Avionics, Flight Dynamics, and Materials—continued under a new structure, the Air Force Wright Aeronautical Laboratories (AFWAL), reporting to ASD. Five years earlier, in 1970, Headquarters Air Force had reassigned the Aerospace Research Laboratories at

Wright-Patterson from the Office of Aerospace Research in Washington, D.C., to AFSC. The Aerospace Research Laboratories were disbanded when the AFWAL was created in 1975. As the Cold War escalated during the Reagan presidency, AFSC again changed the framework for Wright-Patterson's laboratories, redesignating the AFWAL as the Wright Research and Development Center in 1988, and as simply the Wright Laboratory in 1990.[142] In July 1992, the Air Force recombined AFSC and AFLC into a single command, Air Force Materiel Command, returning full circle to a unified logistics-R&D command paralleling Air Materiel Command at the outset of the Cold War. As one of four super laboratories, the Wright Laboratory had remained attached to ASD (and subsequently, the Aeronautical Systems Center) until 1996, when the Wright Laboratory became part of the Air Force Research Laboratory along with three other research centers at Hanscom and Kirtland Air Force Bases in Massachusetts and New Mexico, respectively, and at Rome, New York (see Volume II, Chapters 5, 8, and 12).

Key Associated Architects and Engineers

Key architectural-engineering firms working at Wright-Patterson Air Force Base during the Cold War, or responsible for late World War II buildings that were critical for early Cold War programs, included those listed below. Each of the firms is referenced in discussions in Volume I or in other chapters of Volume II, as noted:

- Black & Veatch, of Kansas City (Volume II, Chapter 4);
- Leo A. Daly, of Omaha (Volume II, Chapter 4);
- Ganteaume & McMullen, of Boston (Volume II, Chapter 11);
- Giffels & Rossetti, of Detroit (Volume II, Chapter 11);
- Hazelet & Erdal, of Cincinnati (Volume I, Part III);
- Holabird, Root & Burgee (Volume I, Parts III and IV);
- Ralph M. Parsons, of Los Angeles (Volume II, Chapter 3);
- Roberts & Schaefer, of Chicago (and Anton Tedesko) (Volume II, Chapter 6);
- Fred N. Severud, of New York (Volume II, Chapter 4);
- Vitro Engineering, of New York (formerly, Kellex) (Volume II, Chapter 4); and,
- Weiskopf & Pickworth, of New York (Volume II, Chapter 8).

---

[1] Air Materiel Command (Frederick A. Alling), *History of the Air Materiel Command 1946*, volume 1, 3.
[2] The reader can trace the broad patterns of lineage for Wright-Patterson Air Force Base in Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989). The Wright-Patterson chapter includes the sequence of installation names through 1982; dates of establishment, construction, and occupancy; base operating units; base commanders; major off-base and detached installations; major changes to operational capabilities; host commands over time; changes in status; and, a year-by-year indexing of units assigned to the base.
[3] Overview histories of the organization and achievements of Wright-Patterson Air Force Base include James F. Aldridge, Dean C. Kallander, Paul C. Ferguson, Laura N. Romesburg, and Henry M. Narducci, *Against the Wind: 90 Years of Flight Test in the Miami Valley* (Wright-Patterson Air Force Base: History Office, Aeronautical Systems Center, Air Force Materiel Command, 1994); Henry M. Narducci, *A Century of Flight: The Evolution of Wright-Patterson Air Force Base* (Wright-Patterson Air Force Base: 88th Air Base Wing, Aeronautical Systems Center, Air Force Materiel Command, August 1999); Aeronautical Systems Center History Office, *Birthplace, Home and Future of Aerospace: The Evolution of Aeronautical Development at the Aeronautical Systems Center* (Wright-Patterson Air Force Base: Aeronautical Systems Center, Air Force Materiel Command, 1999); Lois E. Walker and Shelby E. Wickam, *From Huffman Prairie to the Moon: The History of Wright-Patterson Air Force Base* (Wright-Patterson Air Force Base: History Office, 2750th Air Base Wing, 1986); James F. Aldridge, "A Historical Overview of the Mission and Organization of the Wright Laboratory 1917-1993," Draft (Wright-Patterson Air Force Base: History Office, Aeronautical Systems Center,

Air Force Materiel Command, November 1994); and, James F. Aldridge, "Fifty Years of Aeronautical Research, Development, and Systems Acquisition at Wright-Patterson Air Force Base," draft contribution on behalf of the History Office, Aeronautical Systems Center, for a proposed (but uncompleted) headquarters Air Force 50th anniversary book on United States Air Force R&D. Discussions across the broad range of achievements originating at Wright-Patterson are also dispersed across Parts II-IV of Volume I of the current study, as well as within many of the individual chapters of Volume II.

[4] Lenore Fine and Jesse A. Remington, *The Corps of Engineers: Construction in the United States*, volume in *United States Army in World War II: The Technical Series* (Washington, D.C.: Office of the Chief of Military History, 1972), 618-619.

[5] In the 1950s, Dr. Newmark would become pivotal in developing official Air Force manuals for nuclear-hardened construction and in training Air Force civil engineers in a related graduate-level program at the University of Illinois of the 1960s (see Volume II, Chapter 8). In 1958, Headquarters Air Force called upon Dr. Newmark's firm, Newmark-Hansen and Associates, to assess the feasibility of additional in-place hardening for the Semi-Automatic Ground Environment (SAGE) air defense command posts (see Volume I, Part IV).

[6] Fine and Remington, *The Corps of Engineers: Construction in the United States*, 1972, 620-649.

[7] Air Materiel Command would also erect its Special AMC Warehouse, designed by L.P. Kooken of Baltimore in 1952, at the depot in Dayton (Gentile Depot)—established as a specialized storage depot exclusively for the Signal Section of the Air Corps[7] (see Volume I, Part II and Volume II, Chapters 6, 7, 10, 11, 12, and 13)

[8] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999), 19-35. The Anton Tedesko Archives, maintained by the Civil Engineering Department at Princeton University, contain numerous detailed job lists for ZD construction that chronicle each thin-shell, reinforced concrete commission, as well as drawings and photographs. Between 1934 and late 1943, Roberts & Schaefer listed 45 ZD building clusters designed and engineered by Anton Tedesko in North America. Of these, about half were structures for the Army, Navy, and Marines. The job list counted multiple hangars at a location as a single item for the indicated year of construction. Commissions in Dayton, at Wright and Patterson Fields, and in Columbus numbered eight, with the laminated wooden arch hangars at Vandalia contained on a separate "airfield and hangars" job list.

[9] "Building Bases for Our Air Forces," *Engineering News-Record* 125, 17 (24 October 1940): 50-61. The Airplane Repair Building is a very important structure and may be the work of an as-yet unidentified architectural-engineering firm hired by the Quartermaster Corps—rather than the work of an architect within the agency. The 275-foot clearspan dimension of the hangar's steel arches, as well as its futuristic modular design, also suggests this possibility.

[10] Most often the Transport Squadron Hangar / Operations – Transport Squadron and Flight Test Hangar (at Wright-Patterson, Building 30206) and the Airplane Repair Building (at Wright-Patterson, Buildings 20001, 20009, and 20022) were located near each other—not the case at Wright-Patterson.

[11] Karen J. Weitze, *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training* (San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001), 135ff.

[12] *Ibid*, 119ff.

[13] Pertinent World War II drawings for Roberts & Schaefer, Albert Kahn, and Hazelet & Erdal are held by civil engineering at Wright-Patterson as hard copies, and also exist in a scanned data base. Anton Tedesko signed the title blocks for his firm's work. See: Roberts & Schaefer Company, "Special Hangar with Lean-To. Signal Corps US Army," (Building 20006), drawing series 4204, 25 March 1942; Roberts & Schaefer, "Modification Center Type Hangars and Shop," (Building 20004), job 4307, 2 June 1943; Albert Kahn, Inc., "Airplane Repair Dock Fairfield Air Depot," (Building 30206), job 1836-A, drawing series 6159, 9 February 1940; Allen & Kelley, "30,000 HP Propeller Test Stand," 2 June 1951; and, Hazelet & Erdal, "Static Test Laboratory," (Building 20065), contract W-1945, Eng. 382, 27 May 1943. The Kahn drawings for Building 30206 seem to be for the earlier iteration of the hangar. This is somewhat misleading. Building 30206 is an Operations – Transport Squadron and Flight Test Hangar updated by Fred N. Severud from the original Kahn design. Severud's hangar is an important immediate precursor to the first B-36 hangar of 1944-1945 (also a Severud design) and is distinct from Kahn's work. Cultural resource inventory studies discussing historic properties at Wright-Patterson include: Emma J.H. Dyson, Dean A. Herrin, and Amy E. Slaton, *The Engineering of Flight: Aeronautical Engineering Facilities of Area B, Wright-Patterson Air Force Base, Ohio* (Washington, D.C.: National Park Service, for Air Force Materiel Command, 1993); History Office, Aeronautical Systems Center, *An Historic Tour of Wright-Patterson Air Force Base* (Wright-Patterson Air Force Base: Air Force Materiel Command, 1995); Conran A. Hay, Wendy Zug-Gilbert, Margaret M.M. Pickart, and Douglas Dinsmore, *Documenting the Cold War Significance of Wright Laboratory Facilities Wright-Patterson Air Force Base*

(Columbus, Ohio: Archaeological and Historical Consultants, Inc., for Air Force Materiel Command, February 1996); Roy A. Hampton, Stanley J. Popovich, Donald M. Durst, Charissa Y. Wang, and Cindy Hassan, *Updated Building Evaluations for Historic Significance at Wright-Patterson Air Force Base* (Columbus and Cincinnati: Hardlines: Design & Delineation and International Technology Corporation, for Air Force Materiel Command, 13 October 1998); and, Hardlines: Design & Delineation, *Historic Context Report for Wright-Patterson Air Force Base* (Columbus, Ohio: Hardlines: Design & Delineation, for Air Force Materiel Command, January 1999).

[14] Fine and Remington, *The Corps of Engineers: Construction in the United States*, 1972, 32-110, 440ff.

[15] *Ibid*, 453.

[16] *History of the Air Materiel Command 1946*, volume 1, 47.

[17] *History of the Army Air Forces Air Service Command 1921-1944*, volume 1, 140.

[18] Air Technical Service Command (Irving R. Friend), *History of the Air Technical Service Command 1945*, volume 1, 109, 115.

[19] *Ibid*, 17.

[20] *History of the Air Materiel Command 1946*, volume 1, 40.

[21] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 87ff.

[22] Dyson, Dean A. Herrin, and Amy E. Slaton, *The Engineering of Flight*, 1993, 107.

[23] *History of the Air Materiel Command 1946*, volume 1, 102.

[24] *History of the Air Technical Service Command 1945*, volume 1, 19-21.

[25] *History of the Air Materiel Command 1946*, volume 1, 32-33.

[26] Air Materiel Command (Max Rosenberg), *History of the Air Materiel Command 1947*, volume 1, 18, 27.

[27] *History of the Air Materiel Command 1946*, volume 1, 83-84.

[28] *Ibid*, 86.

[29] *History of the Air Technical Service Command 1945*, volume 1, 118.

[30] Fine and Remington, *The Corps of Engineers: Construction in the United States*, 1972, 456.

[31] *Ibid*, 618, 639-645.

[32] Air Materiel Command, Army Air Forces Technical Base, *Preliminary Master Plan Report* (Dayton: AAF Technical Base, 1947), 6, 10, 15-18.

[33] "Runways for Seventy-Five-Ton Wheel Loads," *Engineering News-Record* 140, 10 (4 March 1948): 82-87.

[34] United States Air Force, *Air Force Technical Base History July – December 1947*, 15.

[35] United States Air Force, "Minutes of the Wright-Patterson Air Force Base Planning Board," 22 October 1948.

[36] Directorate of Installations, Headquarters United States Air Force, "Wright-Patterson Air Force Base," Sheets 1 and 2, master plans of Wright and Patterson Fields, 1 October 1957.

[37] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 22-23.

[38] Anton Tedesko, "Low-Cost Repairs Restore Concrete to Design Strength," *Civil Engineering* 17, 1 (January 1947): 9-12.

[39] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 20ff.

[40] Arthur J. Boase, "Concrete Building Design Trend Shaped by Clear Space Needs," *Engineering News-Record* 135, 16, 18 (October 1945): 136-140; and, "Concrete Meets Unusual Service Requirements," *Engineering News-Record* 145, 12 (20 September 1945): 167.

[41] "Minutes of the Wright-Patterson Air Force Base Planning Board," 24 May 1948, 18, and, 19 May 1949, 13.

[42] Electronic Subdivision, T-3, Engineering, Air Materiel Command, "Facilities Required for the Five Year Program," dated through verifiable internal references to March-July 1946.

[43] Dyson, Herrin, and Slaton, *The Engineering of Flight*, 1993, 150-151.

[44] Electronic Subdivision, "Facilities Required for the Five Year Program," 1946; A.M. Kinney Inc., "Radiological Instrument Test Building," drawing series 35-51-01, June 1952.

[45] Electronic Subdivision, "Facilities Required for the Five Year Program," 1946.

[46] Hazelet & Erdal, "Radar Test Laboratory," contract W-33-015, Eng. 1123, 31 July 1946. The construction contract for Building 20821 with George W. Timmons Company in Columbus dated to 29 June 1946. See annotated photographs held in the 88th Air Base History Office, Wright-Patterson Air Force Base.

[47] Dyson, Herrin, and Slaton, *The Engineering of Flight*, 1993, 211-214; and, Hay, Zug-Gilbert, Pickart, and Dinsmore, *Documenting the Cold War Significance of Wright Laboratory Facilities Wright-Patterson Air Force Base*, 108-115.

[48] Karen J. Weitze and Christy Dolan, *Historic American Buildings Survey for the Marine Corps Air Station, Tustin, Lighter-Than-Air Ship Hangars (HABS No. CA-2707)* (San Diego: KEA Environmental, Inc., for the United States Navy, January 2000).
[49] Information from the University of Akron is posted at www.uakron.edu/archival/arnstein.
[50] Verne Ketchum, "Shop Fabrication of Wood Trusses and Laminated Beams Expedites Erection and Spurs Low-Cost Building," *Engineering News-Record* 141, 18 (28 October 1948): 106-108.
[51] "High Laminated Timber Arches Provide Large Unobstructed Space for Radar Laboratory," *Civil Engineering* 18, 6 (June 1948): 27.
[52] "Dedicated to War and Peace: The RCA Laboratories Building, Princeton, New Jersey," *Architectural Record* 93, 3 (March 1943): 57-62.
[53] Dyson, Herrin, and Slaton, *The Engineering of Flight*, 1993, 211; and, Hay, Zug-Gilbert, Pickart, and Dinsmore, *Documenting the Cold War Significance of Wright Laboratory Facilities Wright-Patterson Air Force Base*, 1996, 108, 114-115.
[54] "Airman Survival is Aero Med's Big Job: Facilities," *Aviation Week* 59, 7 (17 August 1953): 404-409.
[55] "Aerospace Medical Laboratory," XI216, in File "Facilities of WADC 1958 (1942-1959)," Box "Organizations / WADC," Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.
[56] *History of the Air Materiel Command 1947*, volume 1, 158.
[57] *History of the Air Materiel Command 1947*, volume 1, 160-161; Air Materiel Command (Ruth E. Vorce), *History of the Air Materiel Command 1 January – 30 June 1949*, 77-78.
[58] Aldridge, Kallander, Ferguson, Romesburg, and Narducci, *Against the Wind*, 1994, 24.
[59] *History of the Air Materiel Command 1947*, volume 1, 160-161.
[60] *History of the Air Materiel Command 1 January – 30 June 1949*, 48-49.
[61] Air Materiel Command (Frederick A. Alling, Doris A. Baker, Ethel DeHaven, and Max Rosenberg), *History of the Air Materiel Command 1 July – 31 December 1949*, volume 1, 78-79.
[62] *History of the Air Materiel Command 1947*, volume 1, 164.
[63] Air Materiel Command (Doris A. Baker), *History of the Air Materiel Command 1948*, 4.
[64] "New Concrete Test Houses Accommodate 30-Ft. Propellers," *Civil Engineering* 17, 3 (March 1947): 31. Propeller test facilities were for the Hamilton Standard Propellers Division, United Aircraft Corporation, Hartford, Connecticut.
[65] *History of the Air Materiel Command 1 January – 30 June 1949*, 53-54; "Rotor Wing Testing Facilities," drawing 35-05-01, June 1949 and 11 July 1949.
[66] Dyson, Herrin, and Slaton, *The Engineering of Flight*, 1993, 97, 104; Hay, Zug-Gilbert, Pickart, and Dinsmore, *Documenting the Cold War Significance of Wright Laboratory Facilities Wright-Patterson Air Force Base*, 1996, 72-74.
[67] *History of the Air Materiel Command 1 January – 30 June 1949*, 58.
[68] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 178-177.
[69] AAF Technical Base, Wright Field, "Three Fungi Labs, Temperature & Humidity Materials Laboratory Bldg. 16," job #27-5188, 3 July 1946. Annotated as Building 20281.
[70] "Minutes of the Wright-Patterson Air Force Base Planning Board," 23 August 1948. A "No. 8" is not more specifically identified.
[71] Air Research and Development Command (Ernest G. Schwiebert), *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 1, book 1, 86.
[72] Air Research and Development Command, *History of Wright Air Development Center 1 January – 30 June 1952*, volume 2, 329.
[73] Air Research and Development Command, *History of Wright Air Development Center 1 July – 31 December 1952*, volume 2, 725-730.
[74] "Aerospace Medical Laboratory," XI219, in File "Facilities of WADC 1958 (1942-1959)," Box "Organizations / WADC," Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.
[75] "Building 1421," "Building 1420," and "Building 1418 & 1419," files, History Office, 88th Air Base Wing, Wright-Patterson Air Force Base; "Wright-Patterson Air Force Base A.D.C. Facilities Rehabilitation of Existing Buildings," 1 October 1954.
[76] Holabird, Root & Burgee, "Operations Building for Type 4 Station," drawing 60-02-21, 18 October 1949, site adapted for Wright-Patterson Air Force Base 6 December 1954.

[77] The most noteworthy alteration is typically the addition of windows, occurring at Wright-Patterson in early 1987, and with full renovation of Building 11455 during 1995. In addition to a full discussion of the ADCC / ADDC in Volume I, Parts III and IV, see Karen J. Weitze, *Cold War Infrastructure for Air Defense: The Fighter and Command Missions* (Sacramento: KEA Environmental, Inc., November 1999), 79-90.
[78] Lorenz & Williams, "Cable Repeater and Radio Relay Building," 6 August 1965.
[79] United States Air Force, *A Tour of Wright-Patterson Air Force Base*, 27 October 1955, 5.
[80] Air Defense Command, *History of the 58th Air Division (Defense) 8 September 1955 – 30 June 1956*; United States Air Force, *History of Wright-Patterson Air Force Base January – December 1955*, 51. AC&W squadrons assigned to the 58th Air Division (Defense) shifted during its tenure at Wright-Patterson, due to the changing configurations of air defense sectors and the continuing buildout of ADCCs. AC&W squadrons reported for Wright-Patterson as of the close of 1955, for example, had been the 662nd, 783rd, 784th, and 809th.
[81] United States Air Force: *History of Wright-Patterson Air Force Base July-December 1954* and *History of Wright-Patterson Air Force Base January-June 1956*, 53 and 11.
[82] Air Installation Office, Dayton, "PT. of Area 'C' W-P A.F.B. Building Plan," baseline date of 2 February 1945, updated to September 1949. In File "56th Fighter-Interceptor Squadron & 97th FIS," Box "WPAFB Former Units," History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.
[83] United States Air Force, *History of Wright-Patterson Air Force Base 1 January – 30 June 1951*, 60.
[84] "U.S. Army Air Forces Wright Field Areas A and B. Areas Occupied by 97th Fighter Squadron," baseline date of 15 January 1945, updated to March 1951.
[85] A.M. Kinney, Inc., "Fighter Squadron Facilities Site Plan, Grading and Facilities," June 1951.
[86] "Record Three-Hinged Arch Spans 278 Ft.," *Engineering News-Record* 152, 14 (8 April 1954): 33.
[87] "Minutes of the Wright-Patterson Air Force Base Planning Board," 19 January 1956 and 16 August 1956.
[88] Wright-Patterson was also involved in the MB-1 Genie program through ARDC. The Air Force Special Weapons Center at Kirtland, one of the command's test centers, participated in meetings toward the design and engineering of the igloos for the MB-1 Genie in late 1955. Wright-Patterson additionally hosted an ADC Special Weapon System Project Office for the MB-1 Genie, noted as on base in early 1958. See, United States Air Force, *History of Wright-Patterson Air Force Base 1 January – 30 June 1958*, 4.
[89] Weitze, *Cold War Infrastructure for Air Defense*, 1999, 71-78.
[90] *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*, volume 1, book 1, 81.
[91] Air Materiel Command (Frederick A. Alling, Ethel M. DeHaven, Helen Brents Joiner, and Clifford A. Morrison), *History of the Air Materiel Command 1 January – 30 June 1951*, volume 1, 136.
[92] *Ibid*, 123-125. Air Force historian Lori Tagg was preparing a publication on the role of Wright-Patterson Air Force Base in the Korean War for the Aeronautical Systems Center History Office concurrent with the author's work. She graciously permitted the author to read a draft copy of her efforts. Ms. Tagg and the author have reviewed many of the same primary sources, but the author wishes to note that Ms. Tagg's distillation of specific achievements of the WADC makes a contribution to materials presented here. Ms. Tagg's history has now been published. See: Lori S. Tagg, *On the Front Line of R&D: Wright-Patterson Air Force Base in the Korean War, 1950-1953* (Wright-Patterson Air Force Base: History Office, Aeronautical Systems Center, Air Force Materiel Command, 2001).
[93] *History of Wright Air Development Center 1 January – 30 June 1952*, volume 2, 317-318.
[94] Air Research and Development Command (Margaret A. Kennedy and Robert L. Perry), *The Establishment of Wright Air Development Center March – November 1951*, volume 1, 84-88.
[95] Air Research and Development Command (Margaret A. Kennedy, Robert L. Perry, and Max Rosenberg), "New Facilities for WADC," *History of Wright Air Development Center 1 July – 31 December 1951*, volume 2.
[96] *History of the Air Materiel Command 1 January – 30 June 1951*, volume 1, 111-114; *History of Wright Air Development Center 1 July – 31 December 1951*, volume 1, 103-119.
[97] Alexander McSurely, "WADC: $200-Million Research Key," *Aviation Week* 59, 7 (17 August 1953): 99-117.
[98] "Airman Survival is Aero Med's Big Job," *Aviation Week* 59, 7 (17 August 1953): 392-410.
[99] "Aerospace Medical Laboratory," XI214-215, 218, in File "Facilities of WADC 1958 (1942-1959)," Box "Organizations / WADC," Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.
[100] "Pilot's Job Analyzed in Psychology Lab," *Aviation Week* 53, 5 (31 July 1950): 26-27.
[101] Vitro Engineering, "A/C Lab Hi-Temp Test," drawing E-101-250-12, 17 September 1957. Vitro was formerly Kellex. The firm had major responsibilities for instrumentation and structures' planning on the armament test ranges at Eglin during the 1950s.

[102] Directorate of Research, Wright Air Development Center, "Physical Resources of the Aeronautical Research Laboratory," April 1956, in Box "Organizations / WADC," Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base; A.M. Kinney, Inc., "Research Facility—Aeronautical Laboratory," AF 35-06-21, July 1955.
[103] "Aerospace Medical Laboratory," XI213-219, in File "Facilities of WADC 1958 (1942-1959)," Box "Organizations / WADC," Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.
[104] Installations Division, Deputy for Materiel, Wright Air Development Center, "Summary FY 1954 Public Works Program," *WADC Five Year Facilities Program*, in File "Facilities," Box "Organizations / WADC," Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.
[105] Stephen I. Schwartz, U.S. Nuclear Weapons Cost Study Project, The Brookings Institution, "U.S. Nuclear Weapons Research, Development, Testing, and Production, and Naval Nuclear Propulsion Facilities," posted at www.brook.edu/fp/projects/nucwcost/sites.
[106] Installations Division, Deputy for Materiel, Wright Air Development Center: "Summary FY 1955 Public Works Program" and "Summary FY 1956 Public Works Program," *WADC Five Year Facilities Program*, in File "Facilities," Box "Organizations / WADC," Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.
[107] Wright Air Development Center, *Semi-Annual History of the Aircraft Laboratory 1 January – 1 July 1955*, 2, in *Historical Reports January – June 1955*, Aeronautical Systems Center, History Office, Wright-Patterson Air Force Base.
[108] *History of the Air Materiel Command 1 January – 30 June 1951*, volume 1, 132.
[109] Joseph Trnka and William Manley, *Historic Building Inventory and Evaluation of Air Force Plant 4, Fort Worth, Texas* (Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, January 1997), 3-29 – 3-30.
[110] "Minutes of the Wright-Patterson Air Force Base Planning Board," 6 April 1954.
[111] Headquarters United States Air Force, *History of the Assistant Chief of Staff, Installations 1 July – 31 December 1954*, volume 1, part 1, Directorate of Construction section: 19.
[112] Ralph M. Parsons, "Nuclear Engineering Test Facility Engineering Test Reactor Building," drawing AF 35-06-24, 11 April 1956.
[113] Irving Stone, "Architect-Engineers Build for Aviation," *Aviation Week* 65, 15 (8 August 1956): 64.
[114] Directorate of Research, Wright Air Development Center, *Semiannual History Directorate of Research 30 June 1956 – 1 January 1957*, 2, 4-5, History Office, Aeronautical Systems Center, Wright-Patterson Air Force Base.
[115] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1959*, volume 9, 56-57.
[116] William B. Taylor, "The Army Package Power Reactor," *The Military Engineer* 49, 332 (November-December 1957): 425-429, and, Daniel C. King (United States Air Force), Joseph D. Lafleur, Jr. (United States Army), and Walter J. Eager (United States Navy), "Army Training for Nuclear Power Plant Personnel," *The Military Engineer* 51, 341 (May-June 1959): 181-183.
[117] Headquarters United States Air Force, *History of the Assistant Chief of Staff, Installations 1 July – 31 December 1956*, volume 8, 49.
[118] Headquarters United States Air Force, *History of the Directorate of Installations 1 July – 31 December 1957*, volume 6, 39.
[119] *History of the Directorate of Civil Engineering 1 January – 30 June 1959*, volume 9, 43.
[120] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1959*, volume 7, 41-42.
[121] "Concreting a Nuclear-Reactor Base," *Engineering News-Record* 163, 26 (24 December 1959): 33-34.
[122] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1960*, volume 8, 44.
[123] Headquarters United States Air Force: *History of the Directorate of Civil Engineering 1 July – 31 December 1960*, volume 8, 45, and, *History of the Directorate of Civil Engineering 1 January – 30 June 1961*, volume 5, 39.
[124] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1961*, volume 5, 36, 44.
[125] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1963*, volume 2, 12.

[126] Headquarters United States Air Force: *History of the Directorate of Civil Engineering 1 January – 30 June 1961*, volume 5, 37, and, *History of the Directorate of Civil Engineering 1 July – 31 December 1962*, volume 3, 13.
[127] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 January – 30 June 1964*, volume 5, 28.
[128] Headquarters United States Air Force, *History of the Directorate of Civil Engineering 1 July – 31 December 1964*, volume 5, 16-17.
[129] Headquarters United States Air Force: *History of the Directorate of Civil Engineering 1 January – 30 June 1966*, volume 3, 12, and, *History of the Directorate of Civil Engineering 1 July – 31 December 1966*, volume 3, 14.
[130] Leo A. Daly, "Readiness Crew Building 70 Men," drawing AW 30-11-12, 10 April 1958 (adapted for Wright-Patterson Air Force Base 15 December 1958); Giffels & Rossetti, "Operations Building," drawing 30-05-01, 21 January 1959; Giffels & Rossetti, "Industrial Building," drawing 35-34-01, 21 January 1959; Giffels & Rossetti, "SAC Dispersal Facilities Warehouse Building," drawing 33-02-15, 26 January 1959 (adapted for Wright-Patterson Air Force Base July 1959); Southern Engineering and Construction Co., "Dock A/C Fuel Systems," 19 May 1961; Taylor & Gaskin, "Maintenance Docks-Type SHU-1/F Site Plan," 26 September 1958; Ganteaume & McMullen, "GAM-77 / GAM-72 Service Shop," drawing AW 35-01-02, March 1959; Ganteaume & McMullen, "GAM 77 Facilities Missile Run-Up Shop," drawing AW 60-08-04, March 1959; Ganteaume & McMullen, "GAM 72 Facilities Engine Test Cell," drawing AW 60-08-03, January 1959; Black & Veatch, "Ammunition Storage Area Ammo Storage, Multicubicle," drawing AW 33-13-19, July 1958; and, Black & Veatch, "Ammunition Storage Area Ammo Surveillance and Inspection," drawing AW 35-69-05, July 1958.
[131] The "Aeronautical Systems Center" under Air Materiel Command in the late 1950s is distinct from Aeronautical Systems Center today. ASD of AFSC absorbed certain activities within Aeronautical Systems Center of Air Materiel Command at the time of the change from Air Materiel Command / ARDC to AFLC / AFSC. Between 1961 and 1992, "Aeronautical Systems Center" does not exist in the Air Force. ASD superceded the earlier Aeronautical Systems Center, but was also a much more comprehensive organization that included the R&D laboratories formerly within the WADC / Wright Air Development Division. ASD was an AFSC unit from 1961 to 1992. With the reintegration of the logistics and research, development, testing, and evaluation missions of AFLC and AFSC in 1992 as Air Force Materiel Command, "Aeronautical Systems Center" reemerges as an organizational name. The Aeronautical Systems Center of the more recent era is a direct continuation of ASD of 1961-1992.
[132] Aldridge, Kallander, Ferguson, Romesburg, and Narducci, *Against the Wind*, 1994, 28-63.
[133] Weitze, *Eglin Air Force Base, 1931-1991*, 2001, 230-254, 260-267.
[134] *History of the Directorate of Civil Engineering 1 July – 31 December 1966*, volume 3, 30.
[135] Aldridge, Kallander, Ferguson, Romesburg, and Narducci, *Against the Wind*, 1994, 28-30.
[136] Aldridge, "A Historical Overview of the Mission and Organization of the Wright Laboratory 1917-1993," 1994.
[137] Hay, Zug-Gilbert, Pickart, and Dinsmore, *Documenting the Cold War Significance of Wright Laboratory Facilities Wright-Patterson Air Force Base*, 1996, 93-95.
[138] Yosh, Nakazawa & Associates, Inc., "Science Laboratory, Avionics (AVLAB)," drawing AW 35-06-48, July 1962.
[139] Hay, Zug-Gilbert, Pickart, and Dinsmore, *Documenting the Cold War Significance of Wright Laboratory Facilities Wright-Patterson Air Force Base*, 1996, 101, 106, 115, 120..
[140] Sanders & Thomas, Inc., "Science Laboratory Optics," drawing AW 35-06-42, September 1964.
[141] Hay, Zug-Gilbert, Pickart, and Dinsmore, *Documenting the Cold War Significance of Wright Laboratory Facilities Wright-Patterson Air Force Base*, 1996, 96-98.
[142] Aldridge, Kallander, Ferguson, Romesburg, and Narducci, *Against the Wind*, 1994, 33. For lineage details pertinent to the WADC, the Wright Air Development Division, ASD, the AFWAL, the Office of Aerospace Research, and the Aerospace Research Laboratories, see: Michael H. Gorn, *Vulcan's Forge: The Making of An Air Force Command for Weapons Acquisition (1950-1985)*, volume 2 (Andrews Air Force Base: Office of History, Air Force Systems Command, second printing, 1985), appendices 1-5, "Evolution of Aeronautical Systems Division (ASD)," 1-7, "Evolution of Aerospace Research Laboratories (ARL)," and 1-48, "Evolution of Office of Aerospace Research (OAR)."

Chapter 15: Air Force Industrial Plants

Historic Missions of the Cold War

Cold War missions at the four Air Force industrial plants represent only a slice of the many complex endeavors undertaken across the agency's plant program over the 1946-1991 period (see Volume I, Part II for a summary discussion and other individually important examples not detailed here). Aircraft and weapons acquisition through Air Force-owned plants of this era first fell to Air Materiel Command. Within the command, management of the plants changed over time. In 2003, the four remaining plants are subsumed under Aeronautical Systems Center within Air Force Materiel Command. The Aeronautical Systems Center at the turn of the twenty-first century is not to be confused with the Aeronautical Systems Center of the late 1950s under Air Materiel Command. The earlier Aeronautical Systems Center was strictly a unit within the logistics command, while the Aeronautical Systems Center that exists in 2003 manages a much broader program that includes both logistics and research and development (R&D) missions, such as the industrial plants (logistics) and all of the research laboratories at Wright-Patterson Air Force Base in Ohio (R&D) (see Volume I, Part II). When Air Materiel Command became Air Force Logistics Command (AFLC) in 1961, and Air Research and Development Command (ARDC) simultaneously became Air Force Systems Command (AFSC), the Aeronautical Systems Center of Air Materiel Command shifted to AFSC and was absorbed within the newly formed Aeronautical Systems Division (ASD) along with the Wright Air Development Division (before 1959, the Wright Air Development Center [WADC]), which formerly managed the R&D laboratories (see Volume II, Chapter 14). The majority of plant management from 1961 forward was within AFSC under ASD. In 1992, with the reunification of the research, development, testing, and evaluation, and, logistics "halves" of AFSC and AFLC as Air Force Materiel Command, a second Aeronautical Systems Center emerged, replacing ASD. The plant program in 2003, as was true within Air Materiel Command, is again managed within Aeronautical Systems Center.

When Air Materiel Command became AFLC in 1961, considerable debate existed over materiel-and-procurement's ties to logistics—versus its links to R&D. During the preceding years, ARDC had avidly sought the transfer of procurement authority from Air Materiel Command. With the changes from Air Materiel Command to AFLC, and ARDC to AFSC, Headquarters Air Force shifted the three Air Materiel Command Centers (Aeronautical Systems, Electronic Systems, and Ballistic Missiles) to AFSC, while AFLC retained the materiel and procurement functions most directly pertinent to its logistics mission. The transfer of responsibilities included the allocation of the three contract management regions, their subordinate organizations, and the plant representative offices from AFLC to AFSC. The scheduling of the overall transfer was somewhat staggered. As set up, AFSC was to service 27,000 of 33,580 contracts which were previously under the umbrella of Air Materiel Command / AFLC. The 67 Air Force-owned industrial plants and contractor sites on the books in 1961 (see Volume I, Part II) also moved from AFLC to AFSC on a schedule. As the plants transferred between AFLC and AFSC, they fell under the management of Aeronautical Systems Division (within AFSC). Aeronautical Systems Division was one of four initial divisions that replaced the former three centers under Air Materiel Command. (The other divisions within AFSC in 1961 were Electronic Systems Division, Ballistic Systems Division, and Space Systems Division [see Volume II, Chapters 5, 9, and 12].)[1] By the middle 1970s, management of the Air Force industrial plant program had completely shifted to Aeronautical Systems Division under AFSC. Simultaneously, the numbers of plants under Air Force management continued to steadily decrease over time. After the conclusion of the Cold War, when AFLC and AFSC recombined as Air Force Materiel Command in 1992, the AFSC product "divisions" again became "centers." The post-Cold War Air Force industrial plant program fell under Aeronautical Systems Center within the command, and operation of government-owned plants continued to decrease. In 1992, under Aeronautical Systems Center, 13 Air Force industrial plants remained on line. This number shrank to 11 in 1999

and to four by 2003. When the plant program had transferred from Air Materiel Command / AFLC to AFSC in 1961, there were about 74 active Air Force plants (67 of which formally transferred from AFLC to AFSC that year). The program "high" was just over 90 plants, in the late 1950s (see Volume I, Part II).

Primary Missions

The four plants managed under Aeronautical Systems Center in 2003 are Air Force Plants (AFPs) 4, 6, 42, and 44, located in Fort Worth, Texas; Marietta, Georgia; Palmdale, California; and, Tucson, Arizona, respectively. The Cold War missions of these plants included the manufacture, modification, and / or testing for generations of individual aircraft and weapons systems that included:

- the B (bomber) -29 (for the Korean War effort);
- the B-36 and XC (experimental cargo) -99;
- the NB (special bomber) -36H (with involvement in the Aircraft Nuclear Propulsion [ANP] program, 1951-1961) (see Volume II, Chapter 14);
- Lockheed nuclear-powered aircraft and reactor projects;
- the B-47;
- the F (fighter) -86;
- the F-94;
- the Falcon air-to-air missile;
- the F-89;
- the F-100;
- the F-102;
- the F-106;
- the C (cargo) -130;
- the A (attack) -4 (Navy);
- the B-58;
- the C-140;
- components of missiles, space boosters, and drones;
- the B-57;
- the C-141;
- the SR (strategic reconnaissance) -71;
- the U (utility) -2;
- the F-111;
- the C-5;
- the Walleye glide bomb;
- the tube-launched, optically-tracked, wire-guided (TOW) antitank missile;
- the Phoenix air-to-air missile;
- the Maverick air-to-ground missile;
- the F-16;
- the B-1;
- the advanced medium range air-to-air missile (AMRAAM); and,
- the B-2.

Tenant Organization Missions

The four plants did not support true tenant missions of the Air Force or other related military-civilian agencies, although significant tenant missions did exist at Carswell and Dobbins Air Force Bases—

the sites of AFPs 4 and 6. For example, at Carswell Strategic Air Command (SAC) sustained alert duty as of the late 1950s, supporting a 70-man ready crew quarters (molehole) and associated ancillary structures. At Dobbins, Air Defense Command (ADC) assigned the 35th Air Division (Defense) in 1951 to man a first-generation air defense command post on base. The Air Defense Control Center (ADCC) at Dobbins was one of 11 erected in 1950-1952 (see Volume I, Parts III and IV). The presence of these high-profile tenant missions at Carswell and Dobbins likely enhanced the importance and sustained viability of AFPs 4 and 6. At Carswell, a key SAC base, the presence of that command not only was thoroughly interwoven with the manufacture and test of the B-36 at AFP 4, but also directly supported the research, development, testing, and evaluation mission of the WADC for the NB-36H at the plant (see Volume II, Chapter 14). At Dobbins, the dual placement of an ADCC at the installation and assignment of the B-47 (subcontracted for manufacture from Boeing to Lockheed) to AFP 6 during the 1950s was probably also not a coincidence. The B-36 and B-47 were the premier SAC bomber programs of the early Cold War. The Air Force even showcased these two bombers to the public (and to the Soviet Union) through the channels of popular culture. *Strategic Air Command*, a movie of 1954, really had no plot other than the important arrival of the B-36 and B-47 into Air Force inventory. The movie's B-36 segment took place at Carswell.

In several instances, at AFPs 42 and 44, the Air Force also permitted its contractors to use on-site facilities for production of Navy and Army aircraft and weapons systems.

Chronology

Between mid-1940 and 1945, the United States government funded 350 Army and Navy aircraft plants, including ones government-owned, government-operated, and government-owned, contractor operated (GOCO) (see Volume I, Part II). Among the aircraft plants were 290 built as expanded facilities or new construction. Of these, 190 were for the Army and 100 for the Navy Bureau of Aeronautics. Plants manufactured not only whole aircraft, but also airframes, airframe subassemblies, engines, and parts. Twenty-one modification centers were also subsumed within the industrial plant network.[2] Modification Center No. 11, in Vandalia, Ohio, for example, was among the latter group (see Volume II, Chapter 14). Generally, major architectural-engineering firms were responsible for plant design—a situation enhanced for the Army due to augmented civil engineering responsibilities within the Air Corps and its follow-on, the Army Air Forces (see Volume II, Chapter 14). Strong ties to the automotive industry in autumn 1940 also guaranteed that the major architect-engineer for its manufacturing plants would also be involved in the construction of new aircraft production facilities. The Army had placed the aircraft and weapons procurement mission within Materiel Division of the Air Corps (Materiel Command / Air Technical Service Command of the Army Air Forces), emphasizing a contract relationship with the private sector for supply. Most Army aircraft plants were of the GOCO type. In that situation, contracted firms designed the original plant infrastructure (as handled by civil engineering within the Air Corps / Army Air Forces), operated the facilities, and manufactured the needed product, overseen by the government. Leading architectural-engineering firms designing World War II aircraft plants included Albert Kahn and Giffels & Vallet of Detroit, J. Gordon Turnbull and The Austin Company of Cleveland, and Robert & Company of Atlanta. Kahn's firm had previously contracted to both the automotive industry and the military, additionally responsible for notable Ford plants overseas. The dominance of firms from the upper Midwest was striking, linked in part to events unfolding between the Air Corps and the Ohio River Division of the Army Corps of Engineers, and in part to Detroit's role for auto manufacture. The overall role of the Midwest as the premier heavy manufacturing center of the country, and the importance of Chicago as one of two American cities internationally known for architectural and engineering excellence (with New York the other), also contributed (see Volume II, Chapter 14).

After the war, the government most often attempted to sell its excess industrial plants to the firms operating them, with little success in the uneven economic years of the late 1940s. In 1946, Air Materiel Command cut its aircraft procurement to 10 percent of what it had reached in 1945. Preparedness for future conflicts, however, where mobilization was speedily desired, mandated a new approach to long-term military industrial readiness. Simultaneously with the severe cutbacks, the Army Air Forces established nine "standby plants" as the Cold War unfolded. Among the very first of the reserved plants were five GOCOs: in Omaha, Nebraska (Martin); Kansas City, Missouri (North American Aviation); Tulsa, Oklahoma (Douglas); Fort Worth, Texas (Consolidated Vultee), and Marietta, Georgia (Bell). Known as Government Aircraft Plants (GAPs) and numbered, several of these initial plants would become the AFPs of later in the program. Two of the five, the plants in Fort Worth and Marietta, were continuous in their designations as GAP No. 4 and GAP No. 6—in 2003, AFPs 4 and 6. The Reconstruction Finance Corporation owned the other four earliest plants: in Indianapolis and South Bend, Indiana (Allison and Studebaker); near Cincinnati (Wright); and, in Wichita, Kansas (Boeing). With the exception of the Bell Aircraft plant in Georgia, each of these industrial sites was located deep in the interior of the continental United States. Interior plant locations were in keeping with what would be called the Eisenhower Policy of the early 1950s. By 1949, the Air Force industrial plant program had grown from the nine original standby plants to 26 facilities (government-operated and GOCO). The umbrella standby program had mushroomed to 234 plants within the National Industrial Reserve, of which the Air Force's 26 plants were a part. In early 1951, Air Materiel Command also turned to commercial facilities for aircraft and weapons systems maintenance tasks, augmenting the efforts routinely undertaken at the command's depots (see Volume II, Chapter 11). These commercial auxiliaries included 18 sites: one in Seattle (Boeing), seven in California (concentrated in Los Angeles), one in Tucson (Grand Central Aircraft Company, for work on the B-29), two in Oklahoma / Texas (Tulsa and Dallas), one in southern Florida, one in Marietta (Lockheed, for work on the B-29), four in New York / New Jersey, and one in Cincinnati (North American Aviation, for work on the B-29).[3] By late 1953, the United States government owned 288 plants and, by mid-1954, 47 of these were aircraft production plants.

The Air Force continued to increase its plant infrastructure into the late 1950s, adding missile manufacturing to aircraft production needs. Air Materiel Command also sometimes reacquired facilities sold to the private sector immediately after World War II. In selected cases, plants moved among the military arms. Total number of Air Force aircraft and missile plants reached about 107 by 1958. A 12-year climb in production sites only then began to shift back downwards, with steady divestiture occurring from this point forward. Under AFLC / AFSC, Air Force plants decreased to 70 in 1964, dropping to just over 35 toward the end of the Vietnam War. Numbers of plants continued to shrink through the 1980s to the end of the Cold War, with the program becoming much smaller in the years since 1991. Today, Aeronautical Systems Center within Air Force Materiel Command manages four industrial plants: AFPs 4 (Fort Worth), 6 (Marietta), 42 (Palmdale), and 44 (Tucson). The location of the plants is dramatically different from the sites of the early Cold War, but includes two of the original nine standby plants of 1946 (see Volume I, Part II).

Air Force Plant 4

In late 1940, the War Department had chosen 436 acres west of Fort Worth, Texas, for one of four bomber assembly plants planned for government construction. The Automotive Committee for Air Defense (ACAD), a group of leaders from within the automobile industry asked to advise on aircraft production, had recommended that half of the work needed to manufacture aircraft be allocated to existing automobile plants—reconfigured for the tasks of fabricating aircraft parts and making aircraft subassemblies. The committee had envisioned that the remainder of assembly-line efforts would be ones for the manufacture of aircraft fuselages (one-fourth) and final whole-aircraft assembly (one-fourth). A separate government site selection committee decided upon four locations for the

bomber plants: in Omaha, Kansas City, Tulsa, and Fort Worth. These plants were the very first GOCO aircraft production plants, numbered in 1946-1947 as GAP No. 1, 2, 3 and 4, respectively (see Volume I, Plate 38). The GAP designations translated to the later AFP system still in place today. The Fort Worth plant (AFP 4) was one of three plants set aside for the manufacture of Consolidated's B-24. (Consolidated Aircraft Corporation became Consolidated-Vultee, better known as Convair, following a merger in 1943.) Consolidated was already building its primary plant in San Diego in 1940 when the GOCO program came on line. The company became the contractor for the Fort Worth GOCO, while Douglas Aircraft Corporation agreed to operate the third B-24 assembly plant for Consolidated, that of GAP No. 3 in Tulsa. The aircraft manufacturing process was one of task delegation. While Consolidated had designed, engineered, developed, and tested the B-24, full-scale production fell only partially within its domain. Ford Motor Company received the contract to manufacture kits for the bomber airframes at its own new plant in Willow Run, Michigan (a facility designed by Albert Kahn). Ford shipped the kits to both the Fort Worth and Tulsa plants for the final assembly of B-24s.[4]

The Austin Company of Cleveland designed the bomber plants in Fort Worth and Tulsa, with the two facilities nearly identical. Construction was underway in mid-April 1941, with completion of three main structures by early 1942: the assembly building, the paint shop, and the flight hangar. Supporting ancillary buildings included administration offices, an employee cafeteria, the power and pump stations, and security stations (Plates 201-202). The assembly structure (Building 4) dominated the plant. Steel-frame, faced in brick and metal paneling, two sections comprised the 4,000-foot long Assembly Building. A 200-foot wide unit featured a high bay for the primary assembly line, while alongside it a 120-foot wide secondary space completed the building. The full footprint was 320 feet. Both units ran the length of the structure. In March 1942, Materiel Command hired The Austin Company to add a Parts Plant (Building 5) to the immediate west of the Assembly Building, a structure 2,400 feet long and 350 feet wide. Interior height (with the exception of the high bay area) was uniformly 40 feet throughout both the Assembly Building and the Parts Plant. The plant was a noted achievement within the American engineering community (see Volume I, Part II). Windowless, AFP 4 was of the blackout type. The plant featured an early adaptation of centralized heating, air conditioning, and fluorescent lighting.

Plant responsibilities at Fort Worth during World War II included the initial assignment for B-24 assembly, with an added tasking by autumn 1942 to modify the bomber to a C-87 configuration for cargo transport. AFP 4 also had become a modification center for the B-24 by July the same year. Peak production for the B-24 and C-87 occurred in January 1944, with 200 aircraft accepted that month. In August 1942, AFP 4 began efforts on what would become a major mission of the Cold War, the B-36—although was years from assembly-line production. The Army awarded Consolidated / Convair the contract for the design, construction, and delivery of two XB-36s (the experimental prototype for the bomber) and 13 YB-36s (for prototype service testing, with only one YB-36 manufactured). In December, the Army added the XC-99, the experimental cargo version of the B-36, to Consolidated's contract. AFP 4 and the company's plant in San Diego each participated in efforts for the XC-99. In August 1944, the Army awarded Convair a contract to manufacture 100 B-36s, including related aircraft equipment. Also during 1943-1944, Materiel Command assigned the Fort Worth plant responsibilities for production of the B-32, the Convair follow-on bomber for the B-24. As of December 1944, personnel at AFP 4 had assembled 2,743 B-24s. Convair subsequently converted the plant for the B-32, the B-36, and the XC-99.

The B-36 mission was perhaps the most important production effort during the Cold War for AFP 4, made more so through related R&D endeavors collocated at its SAC host installation, Carswell Air Force Base. The B-36, known as the Very, Very Heavy Bomber (VVHB) during its first years, not

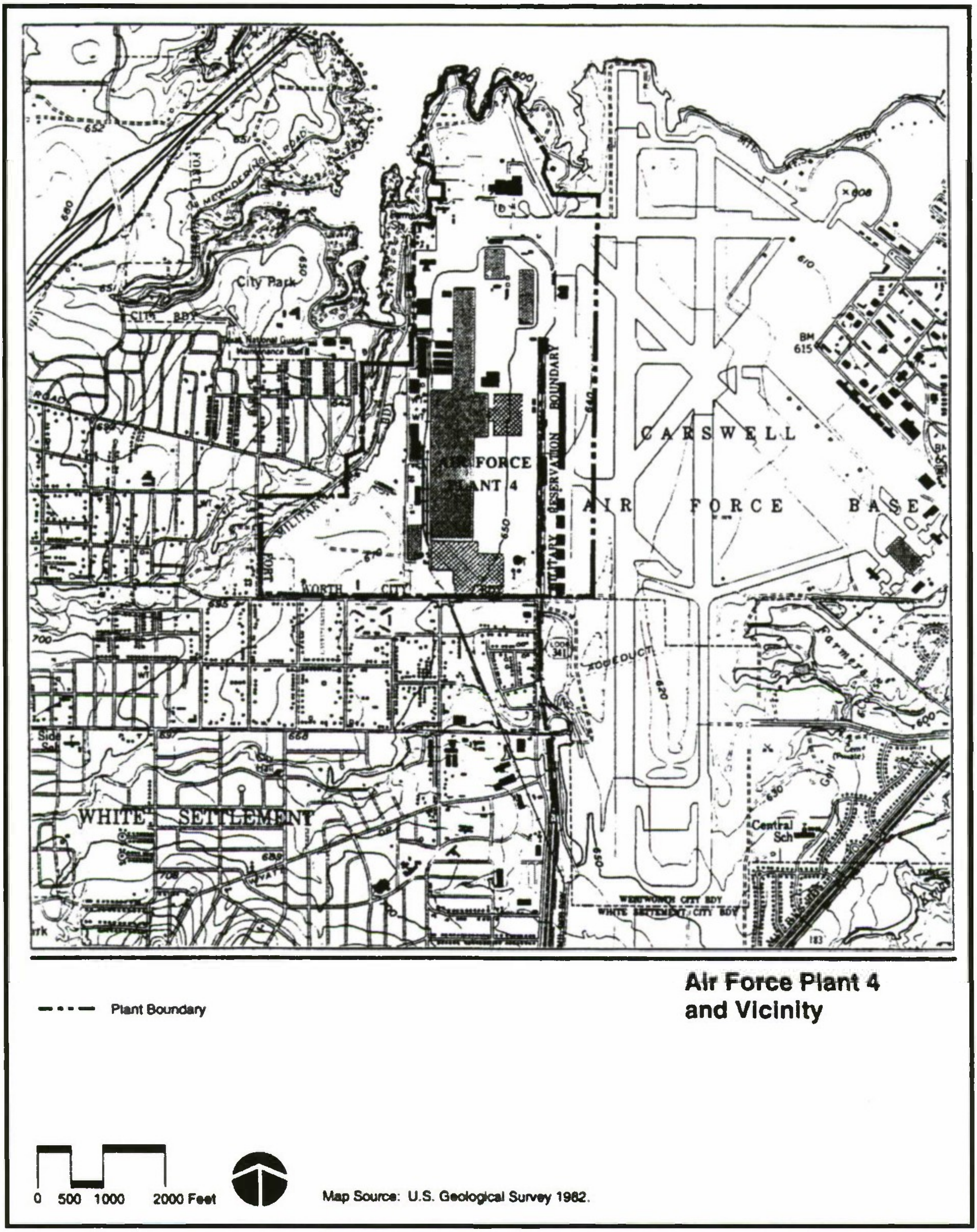

Plate 201: Air Force Plant 4, Fort Worth Texas. In *Historic Building Inventory and Evaluation of Air Force Plant 4*, 1997.

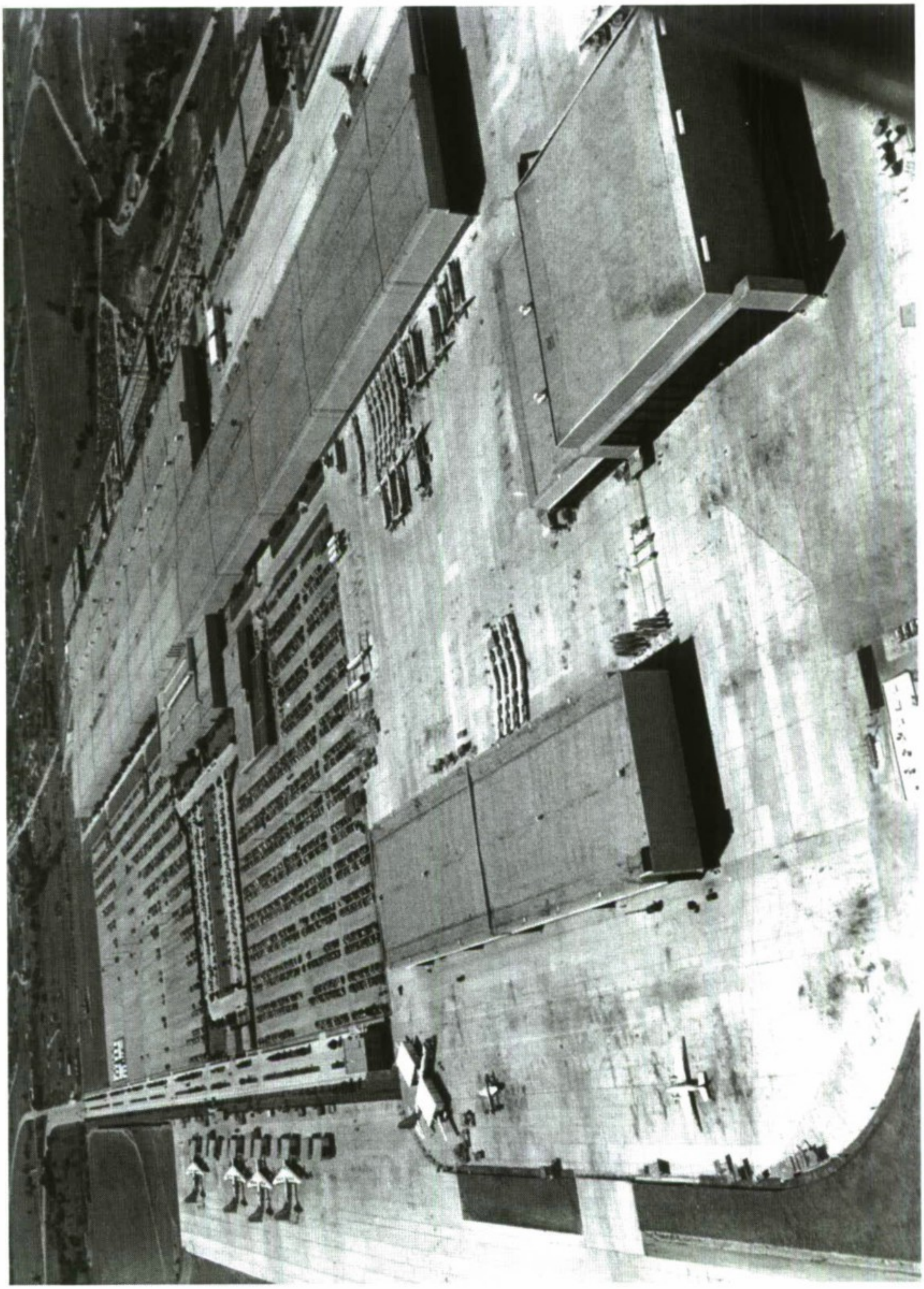

Plate 202: The Austin Company. Air Force Plant 4, Fort Worth, Texas, 1941-1944. Middleground, left: Flight Hangar (Building 8); Foreground, right: Experimental Building (Building 7); Middleground, right: Assembly Building (Building 4); Background, right: Parts Plant (Building 5). Photograph of 1950. Courtesy of Joseph Trnka.

only was an entirely distinct aircraft in size, weight, and capabilities (see Volume I, Part II), but also required newly thought out infrastructure—particularly, runways and maintenance hangars. While Convair requested a heavily constructed runway of 10,000-foot length to accommodate the B-36 in October 1944, the Army Air Forces approved extension of one of the existing World War II runways to just 8,200 feet. Completed in August 1946, Army engineers planned the runway for the bomber's anticipated 240,000-to-300,000-pound weight.[5] Only one other runway was in construction during 1944-1945 explicitly for the B-36, that at the Air Proving Ground at Eglin Field in the Florida panhandle. The Army Air Forces built a 10,000-foot runway at Eglin. A 10,000-to-11,000-foot length and 300-foot width would become the minimum benchmark for a B-36 runway by the late 1940s. Precise engineering for a VVHB runway appears to date to 1947 and was first accomplished in the runway engineered for Patterson Field (Wright-Patterson Air Force Base as of early 1948). In all three cases, the infrastructure was experimental (see Volume II, Chapters 4 and 14). Coupled with a longer, more substantial runway was the need for a large maintenance hangar. At AFP 4, The Austin Company designed the first such hangar, the Experimental Building of 1943-1944 (Building 7). The Experimental Building featured a interior clearspan of 300 by 300 feet, with exterior footprint approximately 326 by 321 feet (Plate 203). Interior clear height was 60 feet. Most restrictive was the width of the aircraft door, at 277 feet: the wingspan for the B-36 was 230 feet. Two other early B-36 hangars followed the design of the Experimental Building at AFP 4 nearly immediately. The hangar at Eglin was an expansible, single-cantilever nose dock designed by New York engineer Fred N. Severud in 1944-1945. Two other airfields are known to have acquired this particular hangar: Fairfield-Suisun Army Air Field (later, Travis Air Force Base) and San Bernardino Army Air Field (later, Norton Air Force Base), both in California (see Volume I, Part II). In 1947, Patterson Field next planned for five VVHB hangars. These structures remained unbuilt, but are assumed to have been planned as thin-shell, reinforced concrete hangars designed by Austrian engineer Anton Tedesko of Roberts & Schaefer (see Volume II, Chapters 4 and 14). In May 1947, Tedesko completed drawings for the thin-shell hangar, erected by SAC just twice at its Rapid City (Ellsworth) and Limestone (Loring) installations in South Dakota and Maine, respectively. The Air Force would select a third hangar, a steel double-cantilever structure in three sizes, for the program buildout of a "B-36 hangar." The Kuljian Corporation of Phlidelphia designed the double-cantilever hangar in autumn 1951—eight years after The Austin Company's design of the Experimental Building at AFP 4 (see Volume I, Part IV).

The XB-36 began engine run-up testing in June 1946, with taxi tests in the next month. The bomber made its maiden flight at AFP 4 in August. The first production-version B-36A flew in late August 1947, followed by delivery of an active-duty bomber to SAC (at Carswell) in late June 1948. In addition to assembly of the B-36A, personnel at AFP 4 handled modifications of the bomber as the series moved forward during the late 1940s into the middle 1950s (the B-36B through the B-36H). The plant delivered the final B-36 to SAC in mid-August 1954, with modifications for the bomber continuing on site until mid-1956. AFP 4 produced a total of 385 B-36s during the mission. Also associated with the B-36 effort was related work toward the XC-99, the cargo version of the B-36 that led to the C-5 of the middle 1960s. Convair manufactured only one XC-99, with the company's efforts split between its primary plant in San Diego and the facilities in Fort Worth. The XC-99 had a slightly wider wing span than its sister B-36 (at 236 feet), but was distinctly longer (by almost 20 feet) and taller (with a tail fin 8.5 feet higher than that of the B-36, giving the plane a total height of 57.5 feet). Manufacture of the XC-99 occupied 1949 into 1950. An Air Materiel Command test program was underway thereafter at Kelly Air Force Base (the San Antonio Air Materiel Area [AMA] depot) from 1950 into late 1959 (see Volume II, Chapter 7). Also an important part of the B-36 program at AFP 4 was modification for the NB-36H. The ANP program was a joint Atomic Energy Commission (AEC) and Air Force effort. Convair built the nuclear test bomber at its Fort Worth plant. The NB-36H carried a nuclear reactor, but flew under its own power (preliminary to

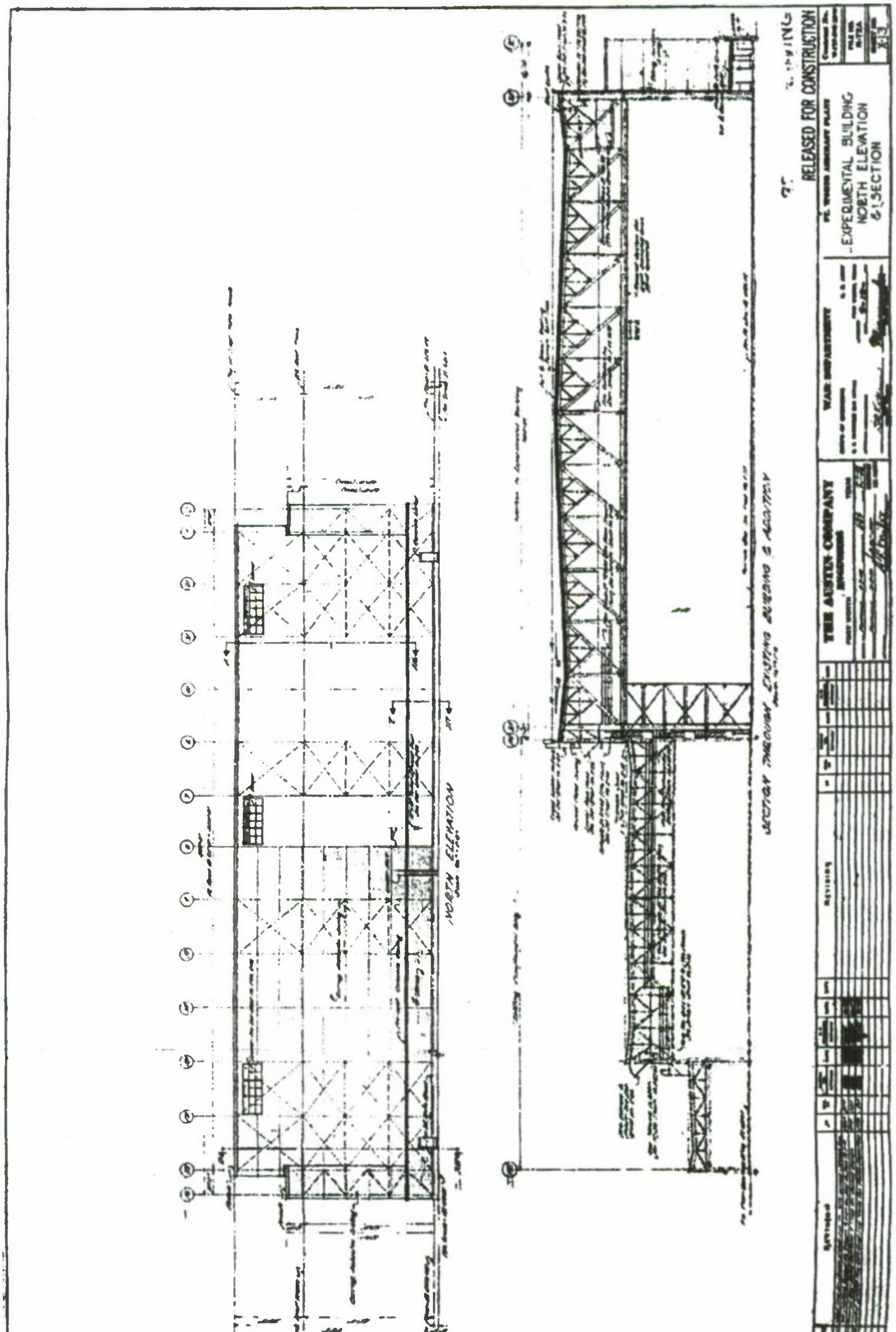

Plate 203: The Austin Company. Experimental Building (Building 7), Air Force Plant 4, Fort Worth, Texas, 1943-1944. In *Historic Building Inventory and Evaluation of Air Force Plant 4*, 1997.

plans for two flying testbeds powered by nuclear energy sources). Under the direction of the WADC at Wright-Patterson, ARDC flight-tested the NB-36H at AFP 4 from 1955 to 1957. The program remained active until President Kennedy formally cancelled it in early 1961 (Plate 204). Other nuclear test facilities in the continental United States were related to those at AFP 4, including a nuclear reactor built at Wright-Patterson (see Volume II, Chapter 14).

Later Cold War missions at AFP 4 included the manufacture of the B-58, B-57, F-111, and F-16. Plant personnel delivered the first Convair B-58, an advanced bomber much smaller than the B-36, in December 1959, with 116 B-58s assembled at the close of production in 1962. In that year, the Air Force contracted with General Dynamics to modify the B-57B and B-57D as high-altitude reconnaissance planes (RB [reconnaissance bomber] -57F / WB [weather reconnaissance bomber] -57Fs) at AFP 4, simultaneously awarding the company development and manufacture of the F-111. The B-57 work lasted into 1963 as an interim mission at the plant. Between 1963 and 1976, General Dynamics (operating the plant following Convair) assembled 562 F-111s in the F-111A through F-111F series. AFP 4 was the sole location for production of the tactical fighter-bomber. In 1975, General Dynamics won the contract to manufacture the F-16. The company initiated a massive production program that included 67 major subcontractors and nearly 4,000 other subcontractors who supplied avionics, components, and equipment to General Dynamics for manufacture of the aircraft at AFP 4. General Dynamics also manufactured the F-16 at plants in Belgium and the Netherlands, with comparable support through major and lesser subcontractors. General Dynamics assembled about 3,000 F-16s by the end of the Cold War in 1991.[6] For all of these efforts, with the exception of the NB-36H project, AFP 4 adapted the existing infrastructure built at the plant during World War II.

Air Force Plant 6

AFP 6 originated as one of the last GOCO facilities built to manufacture heavy bombers during World War II. By 1945, the Army Air Forces supported 12 plants for the B-17, B-24, B-26, and B-29 (Plates 205-206). Boeing's operations for the B-17, B-26, and B-29 accounted for seven of the 12, with Boeing licensing part of its workload to other aircraft manufacturers. The plant in Marietta, Georgia, was a Bell Aircraft Company GOCO that first operated as an additional manufacturing site for production of the Boeing B-29 (see Volume I, Part II). In December 1941, the Army Air Forces had taken steps for a B-29 assembly location near Atlanta.[7] Bell negotiated with Boeing to operate the future plant under a lease arrangement. Robert & Company, a major Atlanta architectural-engineering firm, designed the buildings required for AFP 6 (first known as GAP No. 6) during 1942, with construction underway immediately. Robert & Company initiated drawings for the facility in mid-February, and ground breaking occurred at the end of March. The plant featured brick and steel structures similar to those at AFP 4. AFP 6 was designed as a blackout facility relying on artificial lighting and ventilation. The assembly building (Building B-1) was the main structure for the plant, 2,000 feet long and 1,024 feet wide in footprint. Building B-1 is subdivided into three 120-foot bays, a 300-foot wide main production line area, and side work spaces. At the outset of 1942, the Civil Aeronautics Administration (CAA) had also recently completed the adjacent airfield (later Dobbins Air Force Base), constructing six-inch, soil-cement runways with a two-inch asphaltic-concrete surfacing. The World War II pattern of three runways was shorter than typical, at 4,000 feet. The situation necessitated both expansions and strengthening for the anticipated B-29. While the plant was under construction during 1942-1943, engineers lengthened the three runways to 6,000 feet each (with an improved width of 150 feet). More importantly, construction crews stabilized the existing runways with a three-inch chert cushion. The 1942 runways and their chert augmentation performed as a subgrade for the improved "B-29 runways" of 1943. Uppermost layering for the B-29 runways featured another six inches of unreinforced concrete, laid in flagged sections. Total depth of the finished runways was 17 inches.[8]

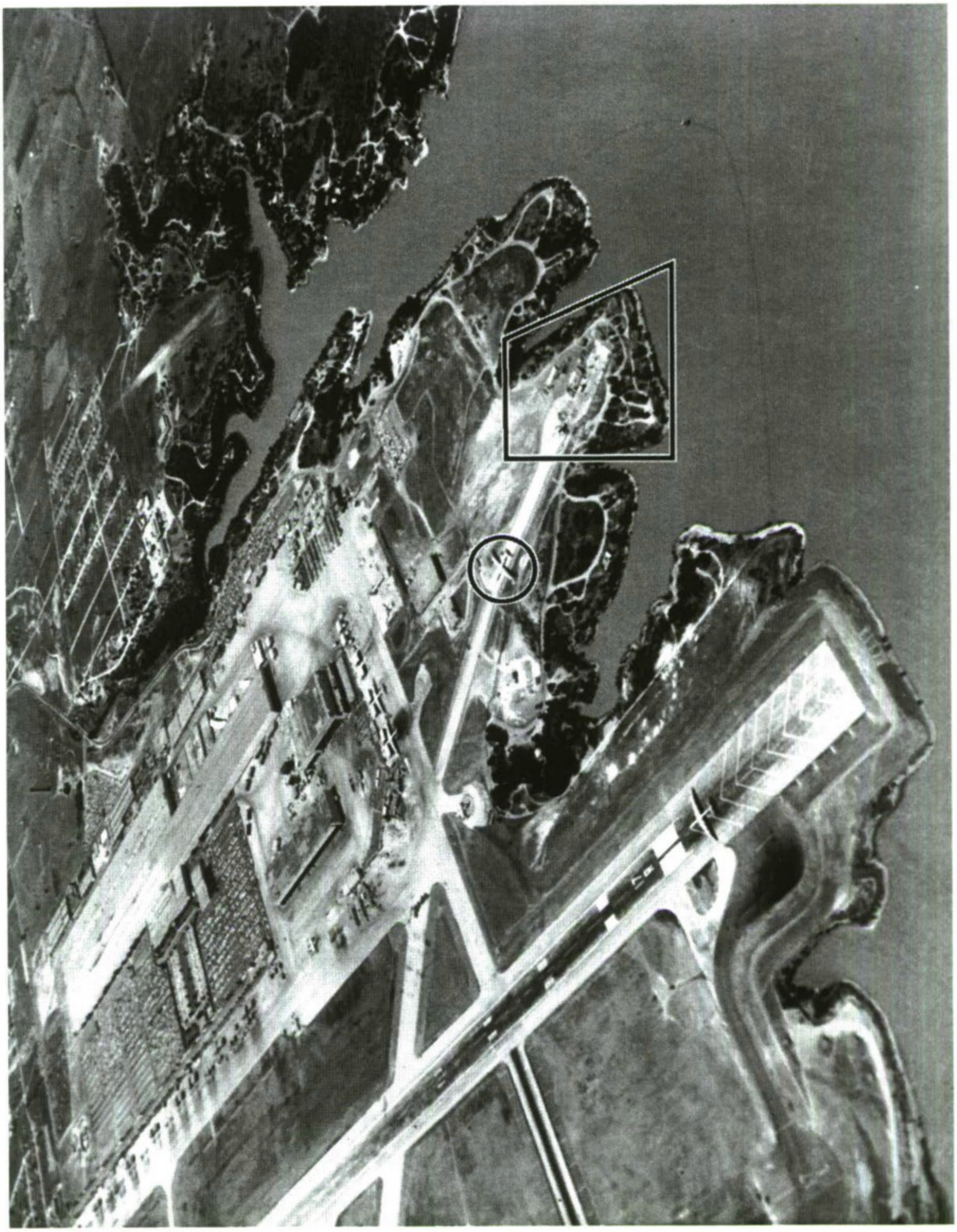

Plate 204: Nuclear Aircraft Research Facility, Air Force Plant 4, Fort Worth, Texas, 1957. The NB-36H is on the taxiway in the test area. (Middleground center.) Annotations added. Courtesy of Joseph Trnka.

Aircraft manufacture at Marietta during World War II was short and the plant's initial production efforts during the Cold War also began slowly. The first B-29 rolled out of the assembly building at GAP No. 6 in November 1943, but with significant tooling problems between Bell and Boeing. Several months earlier, the civilian airfield had become the Cobb County Army Air Field (subsequently, Marietta Army Air Field). Full production at the plant did not start until September 1944, with 668 B-29s assembled by the war's end a year later. Air Materiel Command closed the plant in 1946, although simultaneously designated the facility one of the original nine standby plants for the Army Air Forces (see Volume I, Part II). By 1948, Dobbins Air Force Base was the primary user of the airfield and its associated infrastructure. The Korean War was the stimulus for reactivating the plant at the installation, the kind of rapid mobilization envisioned in the middle 1940s. Lockheed became the contractor for AFP 6 in 1951. Personnel reconditioned mothballed B-29s for combat deployment to Korea. AFP 6 may have received the mothballed aircraft from the 268 B-29s "cocooned" during 1946 in rubberized protective plastic at Robins Field. The program at Robins had been an important one, where men and women had prepared the planes for storage by removing fuel, but otherwise leaving them intact for a speedy refurbishment. Cocooning was an added precaution for aircraft storage that relied on the sprayed plastic technique—not all mothballed aircraft were cocooned. Robins sat to the south of AFP 6, in regional proximity to the plant's facilities (see Volume II, Chapter 11). Also in early 1951, Air Materiel Command selected AFP 6 for manufacture of the Boeing B-47, again in a tiered operational relationship from Boeing to Lockheed. Partially to support the B-47 program, AFP 6 and Dobbins Air Force Base acquired additional buildings and structures. An initial step was an extension of the 6,000-foot runways to 7,500 feet during 1952-1953 (with widening to 200 feet). The Air Force added a fully new 10,000-foot runway for joint Dobbins and AFP 6 use in 1955 (followed by more runway rehabilitation in 1956-1957 that widened the 10,000-foot runway to 300 feet and increased its total depth to 20-24 inches).[9] A key tenant at Dobbins was the 35th Air Division (Defense) as of autumn 1951. The 35th Air Division (Defense) was an ADC mission of very high-profile that directly involved Headquarters Air Materiel Command at Wright-Patterson. Dobbins hosted one of 11 Air Defense Control Centers (ADCCs) for the continental United States of the early 1950s (see Volume I, Parts III and IV, and Volume II, Chapter 13). For the reopening of AFP 6, Lockheed added a flight operations hangar and a radar electronics building, both designed in 1953 by Robert & Company (Buildings B-25 and B-24). Robert & Company patterned the flight operations hangar after a Boeing facility in Wichita, Kansas (at today's McConnell Air Force Base).

The initial B-47 assembled at AFP 6 flew in December 1952. Production for 394 bombers continued steadily until the end of 1957. In July 1954, Air Materiel Command awarded Lockheed a contract for modification, and inspection and repair as necessary (IRAN), for the B-47, a type of assignment more typically undertaken at the command's 10 depots. The middle 1950s diversification of B-47 efforts at AFP 6 also led to the further improvement of infrastructure. Added immediately were 12 nose docks for the B-47 (Buildings T-551 – T-562), planned for task-specific modifications and IRAN. The 1955 nose docks (also called nose hangars) originated as surplus property of unknown source, adapted for the B-47. Each dock featured a prefabricated rectangular structure, sheathed in sheet-metal, manufactured by ARMCO (American Rolling Mill Company / ARMCO Drainage and Metal Products Company of Ohio).[10] ARMCO, IDECO (International Derrick and Equipment Company of Ohio), Butler Manufacturing (of Kansas City), Stran-Steel (of Detroit), and Luria (of New York) were the leading makers of demountable hangars and nose docks of the 1942-1951 period. Drawings illustrate docks varying in footprint from 1,723 to 1,836 square feet. The core structures were approximately of 36.5- by 32-foot dimension, 25 feet tall (Plate 207). Nose nocks and wing hangars for the B-47 are quite rare in 2003. In 1951, Luria, in company with consulting engineer Peter A. Strobel (see Volume II, Chapters 5 and 7), designed the only other known B-47 dock in a swept-wing configuration. McConnell Air Force Base in Wichita, home to a second B-47 Boeing manufacturing

Plate 205: **Air Force Plant 6, Marietta, Georgia. In** ***Historic Building Inventory and Evaluation of Air Force Plant 6*****, 1997.**

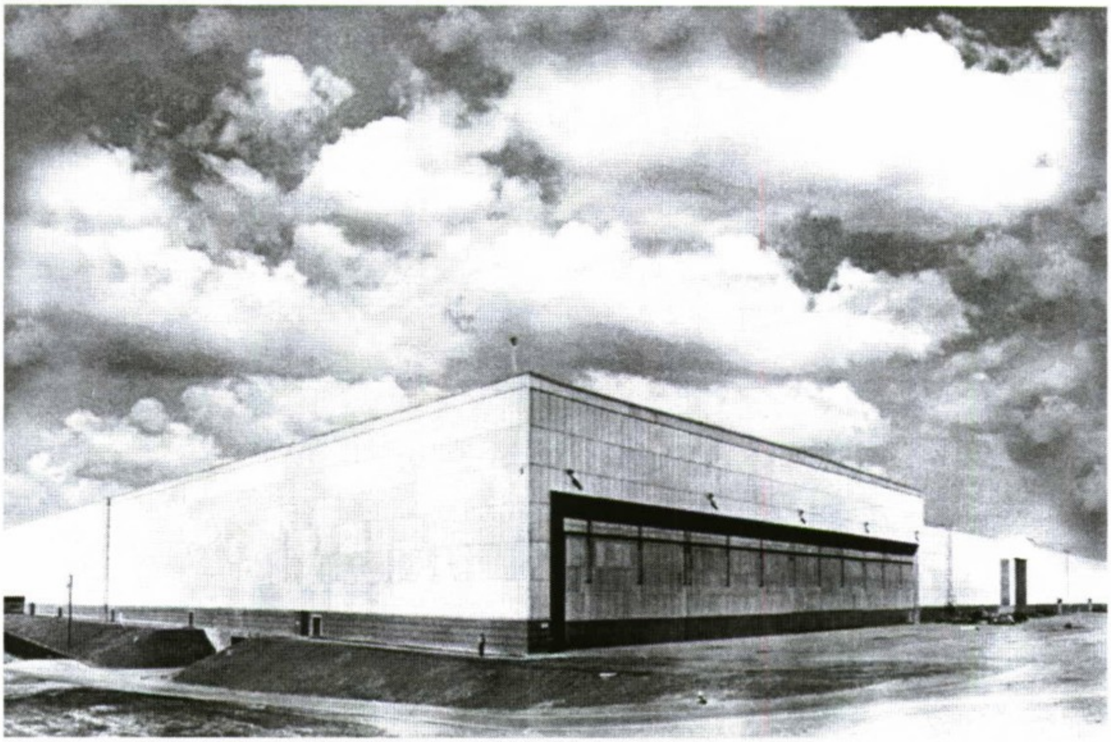

Plate 206: Robert & Company. Main Assembly Building (Building B-1), Air Force Plant 6, Marietta, Georgia, 1942. Undated view. Courtesy of Joseph Trnka.

plant, had a cluster of Luria B-47 docks at this time.[11] Nose and wing docks also existed for the B-36, including transitional structures like ones used at AFP 4 (see Plate 202) and on many SAC bases, and more important docks. A unique group of 10 B-36 docks substituted for a much-needed hangar at Kelly in San Antonio for depot assignments at that base (see Volume II, Plates 95-96). Luria, again working with Strobel, designed the permanent B-36 dock simultaneously with the B-47 dock, in 1951.

In 1956, Lockheed augmented AFP 6 with a modification hangar (Building B-54) "designed" by the architectural-engineering firm Stevens & Wilkinson (Plate 208). Although little is researched about the firm, their hangar for the Lockheed plant relied on a rigid cable-assisted single cantilever that allowed a maximum interior clearspan for large aircraft. Stevens & Wilkinson configured the hangar as two side-opening structures built back to back, each 620 feet long (multi-bay) by 100 feet deep, with center shop area.[12] The baseline structure is nearly identical to one designed for the Navy by Willigoos, Strobel, Panero & Knoerle in the late 1950s (as a single, side-opening, rather than doubled, hangar). In the doubled version of the design—as at AFP 6—the hangar resembles an electronics test hangar designed for Raytheon at Hanscom Air Force Base near Boston in 1958-1959 (see Volume II, Plate 74). Cable-assisted cantilever hangars of varied design, both civilian and military, were a new and notable phenomenon of 1956-1959.[13] The Navy—the leading military user for this type of hangar—relocated its Naval Air Station from Atlanta to new facilities adjacent to AFP 6 and Dobbins Air Force Base during 1956-1958. The presence of the Navy as a tenant at Dobbins was perhaps not a coincidence. Stevens & Wilkinson is assumed to be a regional firm hired by the Atlanta District of the Army Corps of Engineers for Building B-54. The Corps often used existing designs of the Air Force for needed hangars, and conceivably could also have followed this methodology by sending out a baseline set of drawings to Lockheed and the Air Force at AFP 6 for a desired Navy hangar.

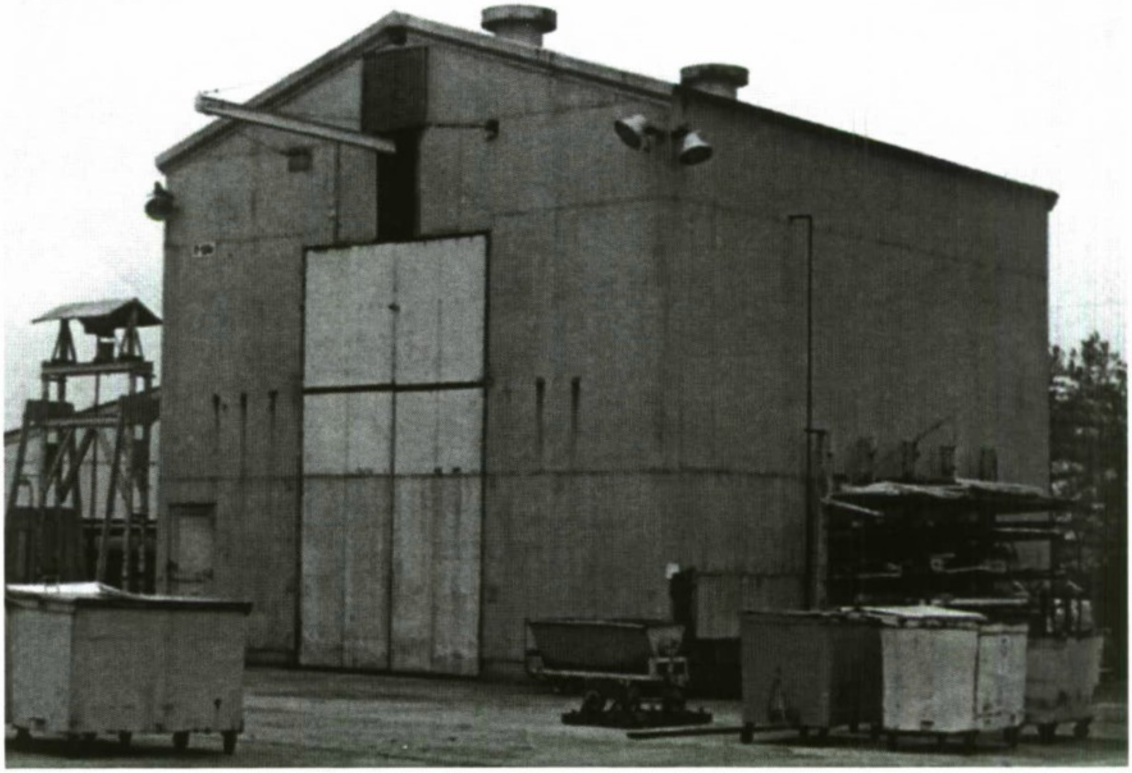

Plate 207: ARMCO. B-47 Nose Dock (Building T-557), Air Force Plant 6, Marietta, Georgia, 1955. Photograph of February 2000. K.J. Weitze for EDAW, Inc.

Although unconfirmed, it is very likely that the role of Stevens & Wilkinson was one of site adaptation and construction management for Building B-54, and that the architectural-engineering firm actually responsible for the hangar's design is either Willigoos, Strobel, Panero & Knoerle or a precursor of that partnership. The "Strobel" of the firm is engineer Peter Strobel, while "Panero" is Guy Panero, a major architect-engineer who had worked on the Army's underground pilot that in the late 1940s in a program directly paralleling that for the Air Force underground pilot plant designed by J. Gordon Turnbull (see Volume 1, Part III). The 12 B-47 modification docks bracketed Building B-54 on its two westerly facades. Over time, Lockheed moved four of the docks to northeasterly locations near Building 5-58, a Butler hangar added to the area in 1957.

During the early to middle 1950s, Lockheed further expanded its operations at AFP 6. In late 1952, Lockheed received the production assignment for the C-130 transport aircraft. The first model of the C-130 flew in April 1955. By mid-1955, the Georgia Division of Lockheed physically augmented the plant through an addition of 140 acres to support future design and research efforts by the company. The land and its facilities were Lockheed-owned, over time housing laboratories and test structures for internal corporate R&D. In 1958, the Georgia Division of Lockheed contracted with the Oklahoma City AMA at Tinker Air Force Base to convert 12 B-47s to unmanned drones (the

Plate 208: Stevens & Wilkinson (baseline design attributed to Willigoos, Strobel, Panero & Knoerle). Modification Hangar (Building B-54), Air Force Plant 6, Marietta, Georgia, 1956. Photograph of February 2000. K.J. Weitze for EDAW, Inc.

QB [drone bomber] -47) for a SAC program to simulate Soviet medium bombers in tests against the Distant Early Warning (DEW) radar line and its related network in Alaska, the White Alice Communications System (WACS). In late 1960, ADC used the QB-47 to test the Semi-Automatic Ground Environment (SAGE) air defense system for the southeastern United States. Air Force personnel picked up the drone, flying as a Soviet bomber, at the SAGE Direction Center at Gunter Air Force Base in Montgomery, Alabama. The Direction Center at Gunter was a training facility for SAGE during its initial operations, a situation that caused extreme problems during the Cuban missile crisis of 1962 (see Volume II, Chapter 13). Personnel at the Gunter Direction Center scrambled Bomarc (Boeing Michigan Aeronautical Research Center) missiles to intercept the QB-47 intruder as a part of the SAGE exercise. Lockheed also participated in the ANP of ARDC / AFSC, operating AFP 67 in nearby Dawsonville (the Georgia Nuclear Laboratory) until its closure in 1971 (see Volume II, Chapter 14). The Georgia Division of Lockheed additionally worked on the design of small nuclear reactors used for training and transportable on a C-130. The C-130 derived from the Lockheed 10-passenger JetStar. Production of the C-130 for the Air Force began at AFP 6 in 1956. The Air Force ordered a number of these transports in a customized contract of 1959, stepping up routine assembly during the late 1950s into early 1960s as well. The Warner Robins AMA at Robins Air Force Base south of Macon received the prime maintenance, modification, and overhaul assignment for the C-130, with the first C-130 arriving at that depot in 1958 (see Volume II, Plates 151-152).

Work at AFP 6 during the 1960s through the 1980s included Lockheed contracts to develop and manufacture the C-141 and C-5 transports, work on the Saturn booster, and continued production of the C-130. Personnel at the plant completed assembly of the first C-141 in August 1963, with a maiden flight at Dobbins in December. Initial work toward the C-5 began in mid-1964. Lockheed, Boeing, and Douglas competed for the huge transport aircraft through the development phases. The Air Force awarded Lockheed the manufacturing contract for the C-5 in late 1965. The C-5 was the world's largest aircraft, from its first flight in mid-1968 until superceded by a Soviet plane in late

1982. Personnel at AFP 6 assembled 80 C-5As through the completion of production in the middle 1970s. In December 1982, Lockheed also won the contract to manufacture the C-5B, an improved version of the transport. Production of the C-5B ended in 1989. AFP 6 continued to augment its individual facilities on site for work on the C-130, C-141, and C-5. Buildings included a paint hangar of 1963 for very large aircraft (Building B-78), an aircraft modification hangar of 1964 (Building B-84), and an empennage mate-and-trim building of 1967 (Building B-102). For a period of time, AFP 6 included a bird-gun platform for firing tests on the windshield of a C-141A. The test platform was set up in front of two B-47 nose docks (Buildings T-557 and T-558).[14] Present by early 1963, the bird-gun test facility was similar in its purpose to the chicken gun of 1972 at the Arnold Engineering Development Center (AEDC) (see Volume II, Chapter 1). During the middle 1960s too, Lockheed worked on a contract for a proposed Airborne Warning and Control System (AWACS) aircraft—Lockheed's version based on the C-141. (Boeing won the final contract for the AWACS, and subsequently manufactured the E [electronic] -3.) AWACS was a radar-equipped plane. In 1965, Lockheed added radar transmitting and receiving structures at AFP 6 (Buildings T-606 and B-90). Throughout the later Cold War, Lockheed-Georgia continued sophisticated R&D analysis at its Marietta facilities.

Air Force Plant 42

Palmdale Airport in Southern California first accrued a military use at the outset of 1935. The Army stationed aviation units there, tied to training efforts on the nearby dry lake beds now part of Edwards Air Force Base.[15] In 1940, men from the Works Progress Administration (WPA) improved the airfield through the addition of a 7,000-foot long reinforced concrete runway, poured in 25-foot squares (flags) eight inches deep on their edges and five inches deep across the center.[16] Construction of the runway was reasonably typical for the first heavy bombers of World War II, but was nearly 2,000 feet longer than most Army runways of the period (see Volume II, Chapter 14). The Army acquired the Palmdale Airport in December 1942 as a sub-base for Muroc Army Air Field (the future Edwards). Palmdale Army Air Field served primarily as a training station for squadrons rotating to the bombing and gunnery ranges associated with Muroc. The Army added two runways of the standard one-mile length. Other infrastructure was of mobilization type and included a Butler prefabricated hangar that continued in use at AFP 42 during the Cold War. In mid-1944, the Army transferred the 445th Fighter Squadron, and the 412th Fighter Group under which it was subsumed at Muroc, to Palmdale Army Air Field—in large part due to spatial constraints at Muroc and the need for expanded flight testing. To accommodate this late-war augmentation, the Army repaired Palmdale runways and added the Butler prefabricated hangar (Building 531). Tests by the 412th Fighter Group focused on the evaluation of experimental and prototype jet aircraft, interwoven with efforts at Muroc and concentrated on the Lockheed XP (experimental pursuit) -80 and the Bell P (pursuit) -59. The first all-jet squadron rotated from Muroc to Palmdale. Immediately after World War II ended, the Army declared Palmdale Army Air Field surplus, selling the site to Los Angeles County for a return to airport use.

By the late 1940s, both the City of Los Angeles and private industry were canvassing all surrounding airfields for potential expansion to meet local aircraft manufacturing requirements. In 1949, the Los Angeles Chamber of Commerce and Lockheed Aircraft each included the Palmdale Airport in their site studies, and in mid-December 1950 Lockheed began to lease facilities and acreage at Palmdale for a flight test and assembly operation there. Lockheed prepared a master plan for the airfield location, with tentative industrial sites also initiated for North American Aviation and Northrop. Planning activities went forward through 1954. By late 1951, the Air Force decided to buy nearly 5,000 acres at the Palmdale Airport. Movement toward a GOCO arrangement was in place. Lockheed hired the Los Angeles architectural-engineering firm of Pereira & Luckman to prepare its formal master plan (Plate 209). The firm also completed multiple airfield master plans for the Air

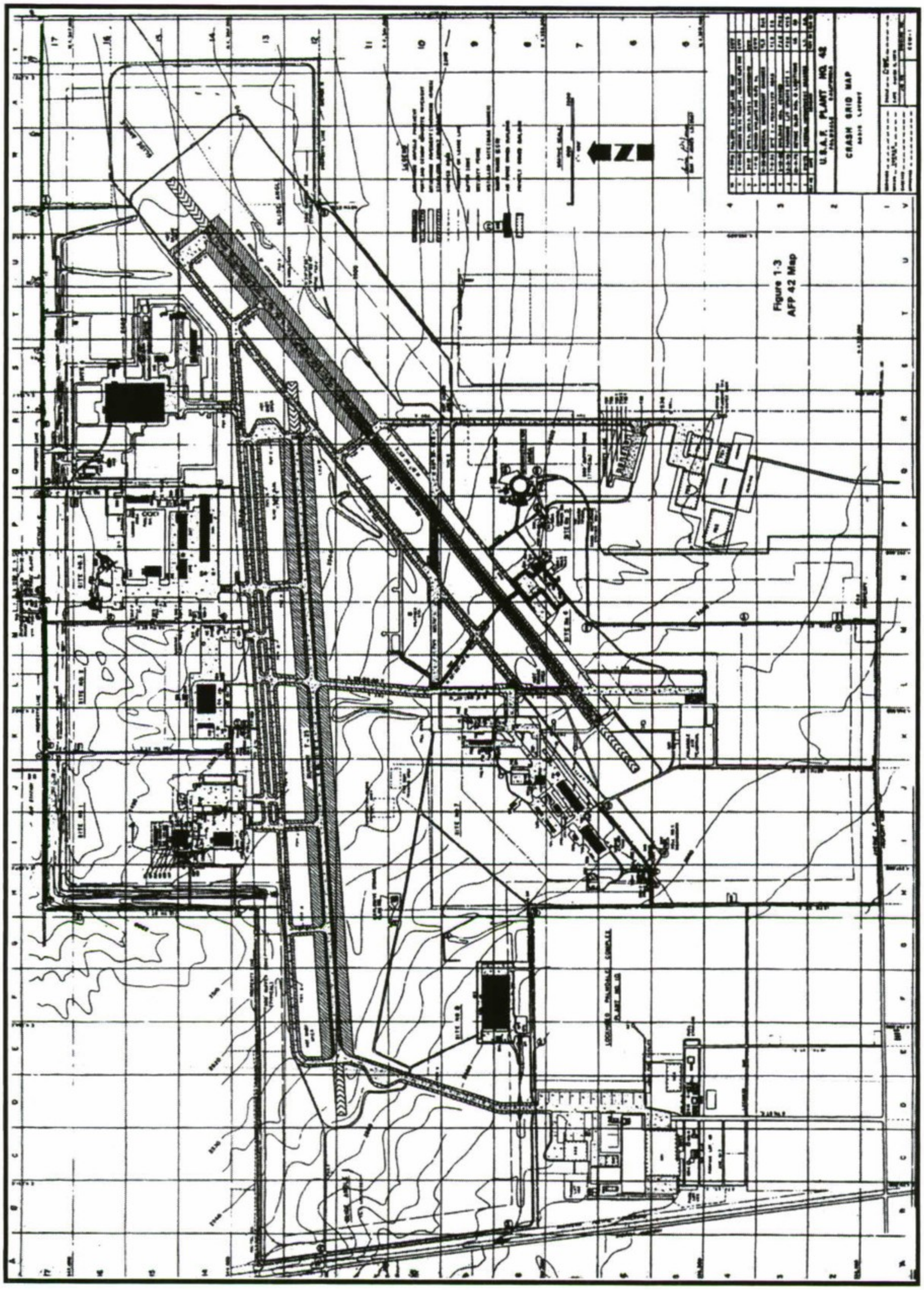

Plate 209: Air Force Plant 42, Palmdale, California. United States Air Force Crash Grid Map, 6 March 1973. In ***Historic Building Inventory and Evaluation of Air Force Plant 42*****, 1997.**

Force in the continental United States and overseas during the early 1950s. Pereira & Luckman executed the master plan for Edwards simultaneously with its work for Palmdale in 1951 (see Volume II, Chapter 3). By September 1954, contractors working at AFP 42 expanded to include Convair. Lockheed remained the primary contractor through the planning process, assigned the responsibility of building joint-use facilities and hiring architectural-engineering firms to that end. In 1953, Lockheed, on behalf of the Air Force, lengthened the 7,000-foot runway of 1940 to 12,000 feet, widening it from 150 to 200 feet simultaneously. The resultant concrete runway did not include an overlay strengthening of the original 7,000 feet, but did feature a depth of 17 inches for the added 5,000 feet of infrastructure.[17] At Edwards, the Air Force added a state-of-the-art runway, 15,000 feet long, 300 feet wide, and 17 to 19 inches thick, in 1954 (see Volume II, Chapter 3).

Preparations for contractors at AFP 42 in Palmdale mirrored a similar setup at Edwards nearby. Both AFP 42 and Edwards added contractor test facilities at each location during 1953-1958. By the middle of 1953, 18 aircraft contractors worked on site at the Air Force Flight Test Center at Edwards, with over 1,300 contractor personnel at that base. Contractors at AFP 42 worked with their counterparts at Edwards in testing experimental and prototype aircraft. North American Aviation, Northrop, Douglas, and Convair each maintained high-profile test centers at both Air Force locations (see Volume II, Chapter 3). At both the plant and the Flight Test Center, contractors operated in discrete areas—at Edwards with assigned flight test hangars and at Palmdale with segregated contractor operating sites within AFP 42. During the Cold War, AFP 42 featured seven separate contractor sites, with five under construction during 1953-1956. Contractors at each site changed over time, directly tied to their work on specific aircraft and again parallel with the procedural situation at Edwards. Responsibility for hiring architectural-engineering firms to design aircraft and flight test hangars appears to have fallen to the individual contractors, with Lockheed having the majority of that task during the first years. Many original drawings for the facilities are missing however, and others have not been completely analyzed. Work to date has documented the participation of at least two major firms, those of J. Gordon Turnbull of Cleveland (with an office in Los Angeles) and Holmes & Narver of Los Angeles. Both firms were in very high standing for important projects under Headquarters Air Materiel Command from the late 1940s forward (see Volume I, Part III and Volume II, Chapter 4).

The first contractor compounds operational at AFP 42 were Sites 1, 2, 3, 5, 7, and 8. Directly controlled by the Air Force, Site 5 was the common area for the plant, and included the runways, taxiways, and aprons for the overall facility, as well as a small number of buildings. The World War II Butler hangar at Site 5, Building 531, is the oldest remaining structure at AFP 42. During the 1950s, North American Aviation, Convair, and Hughes Aircraft sequentially operated in the hangar, but as of 1960 the structure has been primarily used for general maintenance tasks plantwide. AFP 42 added a second, new east-west runway during 1956. At the west end of this runway, the Air Force also built a large-scale tunnel, stocked as a public fallout shelter for the Los Angeles area and able to accommodate 3,400 people for two weeks. Like the original runway improved during the early 1950s, the east-west runway was 12,000 feet long. The runways at AFP 42 were in constant use by the aircraft contractors, and as such underwent multiple instances of upgrade. During 1967-1968, the Air Force improved the earlier runway (which was a composite of the 1940 original infrastructure and the 1953 extension) by adding just under six inches of asphalt surfacing. Next, between 1968 and 1970, the Air Force overlaid the 12,000-foot runway of 1956 with a continuous-pour of concrete, using computer analysis to calculate needed thicknesses throughout the infrastructure. Touchup for the second runway occurred in the middle 1970s. Not until early 2000 did the Air Force completely redo the runway of 1940 / 1953, replacing the concrete to a depth of 14 to 17 inches to handle the heaviest aircraft.[18]

Among the contractor sites, Site 7 was the first in active use after the common area. Lockheed began leasing this area in 1950. The company's initial test structures included assembly buildings, a flight test hangar, and a maintenance building (Plate 210). Design and construction dated to 1953-1954, with J. Gordon Turnbull responsible for at least the flight test hangar (also known as the production flight building) (Building 730). The flight test hangar featured two large bays, each 300 feet wide and 150 feet deep, with 40-foot height clearance through the aircraft doorways. J. Gordon Turnbull may also have executed the master drawings for the assembly buildings (Buildings 720 and 740). The firm is verified as additionally responsible for one structure at Site 3, Building 301 (a production flight building) in 1956. Lockheed managed the planning for contractor industrial sites at AFP 42, including its own site and those of other companies. Lockheed reasonably would have hired one prominent firm, here J. Gordon Turnbull, to execute designs for all buildings of the 1953-1956 period. The individual contractors may then secondarily have hired other local Los Angeles firms to handle final site adaptations and changes. Lockheed operated Site 7 from 1954 to 1972, working on production of F-94s and F-104s. The company also tested T (trainer) –33s and T-2Vs. As of 1958, Lockheed shared Site 7 with Northrop to accommodate that company's final assembly and flight testing of the T-38, a supersonic trainer. In 1963, Northrop contracted to produce the F-5, continuing to work at Site 7 into 1987. Lockheed decamped the location for most of the 1970s, with McDonnell Douglas assuming umbrella responsibility for the site in late 1971. (Lockheed moved its operations to new facilities at Site 1.) McDonnell Douglas produced the Navy's A-4 at Site 7, complementing its efforts for that aircraft at the former North American Aviation plant in Los Angeles (see Volume II, Chapter 9). An earlier A-4 contract for Douglas at Site 2 was the first instance in which the Air Force allocated facilities at its Palmdale plant to another military service arm. When McDonnell Douglas finished its Site 7 contract for the A-4 at AFP 42, Lockheed moved back into the facilities that McDonnell Douglas had been using—a good example of the overall pattern of contractor

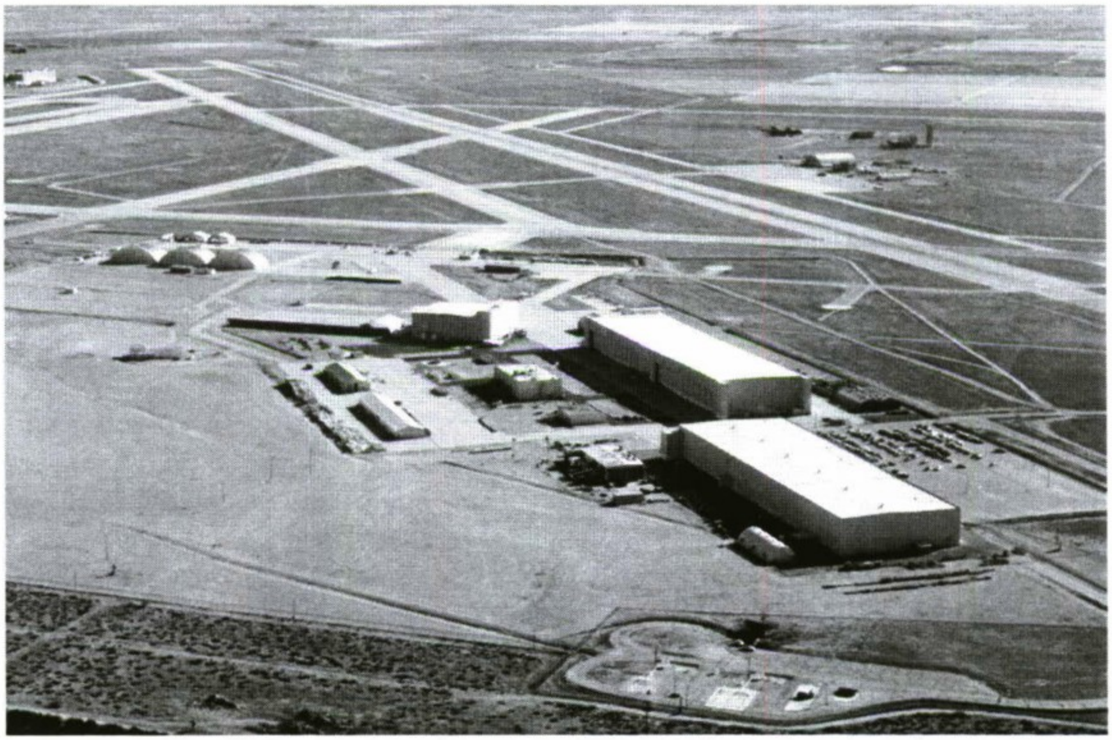

Plate 210: J. Gordon Turnbull. Site 7, Air Force Plant 42, Palmdale, California, 1953-1954. Middleground, left to right: Buildings 740, 720, and 730. Undated view. Courtesy of Joseph Trnka.

facilities operations. Lockheed contracted for work on the TR (tactical reconnaissance) –1 surveillance aircraft and continued at Site 7 on that project until 1987. Site 7 also featured a triple configuration of Butler hangars of unknown specifics. Vought Corporation (also at Edwards) worked in one of these, converting F-86s to drones for the Navy during the late 1970s.

Operations at the other six sites of AFP 42 followed a pattern similar to that at Site 7. The Air Force granted North American Aviation contractual use of facilities at the plant in April 1952 and set up funds to erect permanent buildings for the company's needs. North American Aviation occupied Site 1 from 1954 throughout the Cold War. Its main flight test hangar, designed in 1953 through a regionally well-known Los Angeles firm, closely resembles four flight test hangars designed by Ralph M. Parsons for a group of contractors at Edwards in 1957 (Buildings 1864, 1870, 1874 and 1881) (see Volume II, Chapter 3). Accurate design responsibility for the hangar at Site 1, Building 145, is unknown. At Edwards, North American Aviation first used Building 1870 for work on the X (experimental) -15; at Palmdale, the company produced and modified F-100s and F-86s, also modifying B-52s as carriers for the X-15. During the 1960s, North American Aviation carried out efforts on the XB-70 program (later, aborted). Both Lockheed and Rockwell shared facilities with North American Aviation at Site 1 from the 1970s forward. The companies had plans underway for the B-1 and the Space Shuttle.

Activities at Sites 2, 3, and 8 were all established during the 1950s. At Site 2, Northrop Aviation was the initial contractor at the location, overseeing the construction of the site's permanent buildings. In 1953, Holmes & Narver designed the main aircraft production building at Site 2, Building 210 (Plate 211)—a structure 550 by 345 feet in footprint that included major warehousing and office space. Two years earlier, Air Materiel Command had hired Holmes & Narver for the design and engineering of test buildings for Operation Greenhouse in the Marshall Islands, and in 1945 the firm had designed the Salt Wells Pilot Plant at the Naval Ordnance Test Station at Inyokern, California (China Lake). Greenhouse was among the most prominent of the early atomic aboveground tests, while the Salt Wells facility was the first large-scale production plant for the high explosives used in developing the atomic bomb. Holmes & Narver went on to execute infrastructure for intercontinental ballistic missile (ICBM) launch complexes, as well as a study of facilities needs for a missile-launch base. Illustrative of the overlapping contractor usages at AFP 42 were certainly those at Site 2. Northrop undertook its contract for production and final assembly of the F-89 interceptor at the location between 1954 and 1958; Douglas Aviation, for the Navy's A-4D between 1958 and 1963; North American Aviation, for the XB-70 and F-100 between 1963 and 1964; and, Lockheed, for the SR-71 from 1964 through the end of the Cold War. At Site 3, Convair was the original contractor. Convair was the fourth company to arrive at AFP 42, in mid-1954. J. Gordon Turnbull designed the main aircraft production hangar (Building 301) in 1955 (Plate 212). Building 301 featured three double production bays of 300 by 170 feet that were separated from one another by three-story shop and office spaces. Convair handled production of the F-102 and F-106 at Site 3 from 1956 to 1961, followed by North American Aviation's contract work on the XB-70 into the middle 1960s and Douglas' efforts for the A-4 into the early 1970s. Rockwell also worked at Site 3 on the B-1A and B-1B from the early 1970s into the middle 1990s. The B-1 program required many building modifications. The final of the six 1950s contractor sites at AFP 42 was Site 8, a common warehousing area.

Sites 4 and 6 were both late Cold War additions to AFP 42, established in the middle 1980s as a part of the military buildup during the Reagan Presidency. Site 4 was a Northrop location for production, final assembly, and modification of the B-2 stealth bomber. In 1987, the Air Force provided Site 6 as a small air passenger terminal for military and contractor personnel traveling between AFP 42 and other military facilities. Middle 1980s assembly buildings at the plant included the largest infrastructure at the installation, Building 401 for B-2 production. Other buildings of 1985 at Site 4

Plate 211: Holmes & Narver. Aircraft Production Hangar (Building 210) (right), Site 2, Air Force Plant 42, Palmdale, California, 1953. Undated view. Courtesy of Joseph Trnka.

were an aircraft corrosion control facility (Building 415), an aircraft engine test cell (Building 430), and a second aircraft production hangar (Building 435). Also in 1985-1988, AFSC added a segregated B-2 flight test area at Edwards. The Edwards B-2 area featured a large maintenance hangar, jet engine shop, integrated maintenance facility, research engineering support buildings, and weapons storage area (see Volume II, Chapter 3). The first B-2 flew from its assembly at AFP 42 to Edwards in July 1989, where the bomber began its test program at the Air Force Flight Test Center.

Air Force Plant 44

Hughes Aircraft Company built its industrial plant in Tucson at the municipal airport in 1951 for the manufacture of the Falcon air-to-air missile (Plates 213-214).[19] Hughes had initiated engineering studies and R&D toward the Falcon in 1946 in the company's facilities in San Diego and Pomona, California. Developmental testing for the missile took place at Holloman Air Force Base in New Mexico between 1949 and 1961.[20] Hughes contracted construction of its Falcon plant to the Phoenix company, Del Webb Construction. Falcon Engineering, a group within Del Webb, was responsible for the design of plant facilities. By late 1951, the Hughes Tucson plant was minimally operational. Del Webb Construction completed most buildings during 1952. Hughes immediately sold the plant to the United States government, subsequently contracting to the Air Force to continue its operation as a GOCO. AFP 44 added buildings throughout the 1950s. Huges established three distinct areas within the plant by 1960: a production area, final assembly and checkout area, and

Plate 212: J. Gordon Turnbull. Aircraft Production Hangar (Building 310) (background), Site 3, Air Force Plant 42, Palmdale, California, 1955. Middleground, left to right: Buildings 308, 307, 305, and 333. Foreground, right: Buildings 335 and 336. Undated view. Courtesy of Joseph Trnka.

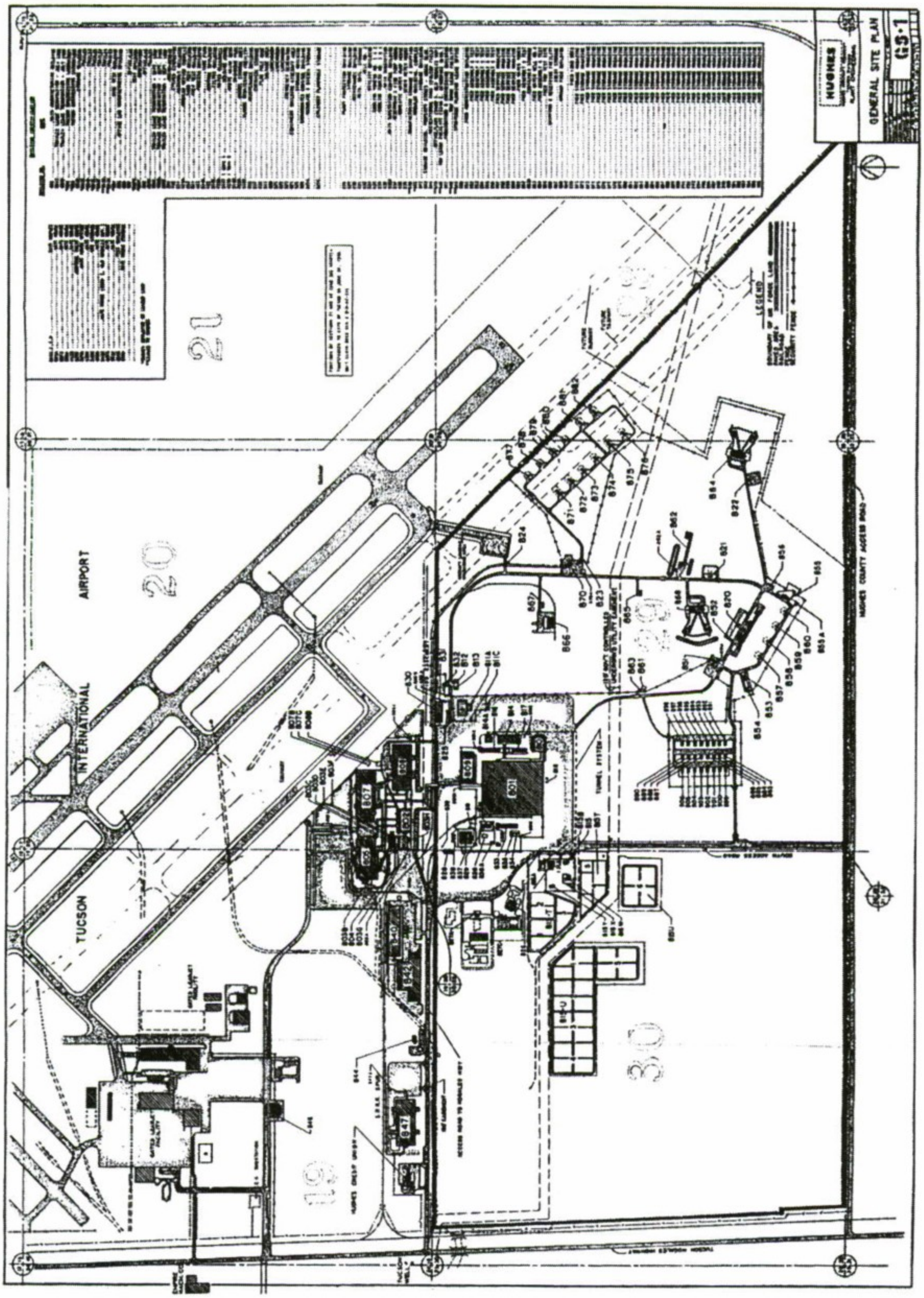

Plate 213: Hughes Aircraft Company. Air Force Plant 44, Tucson, Arizona. General Site Plan. In *Historic Building Inventory and Evaluation of Air Force Plant 44*, 1996.

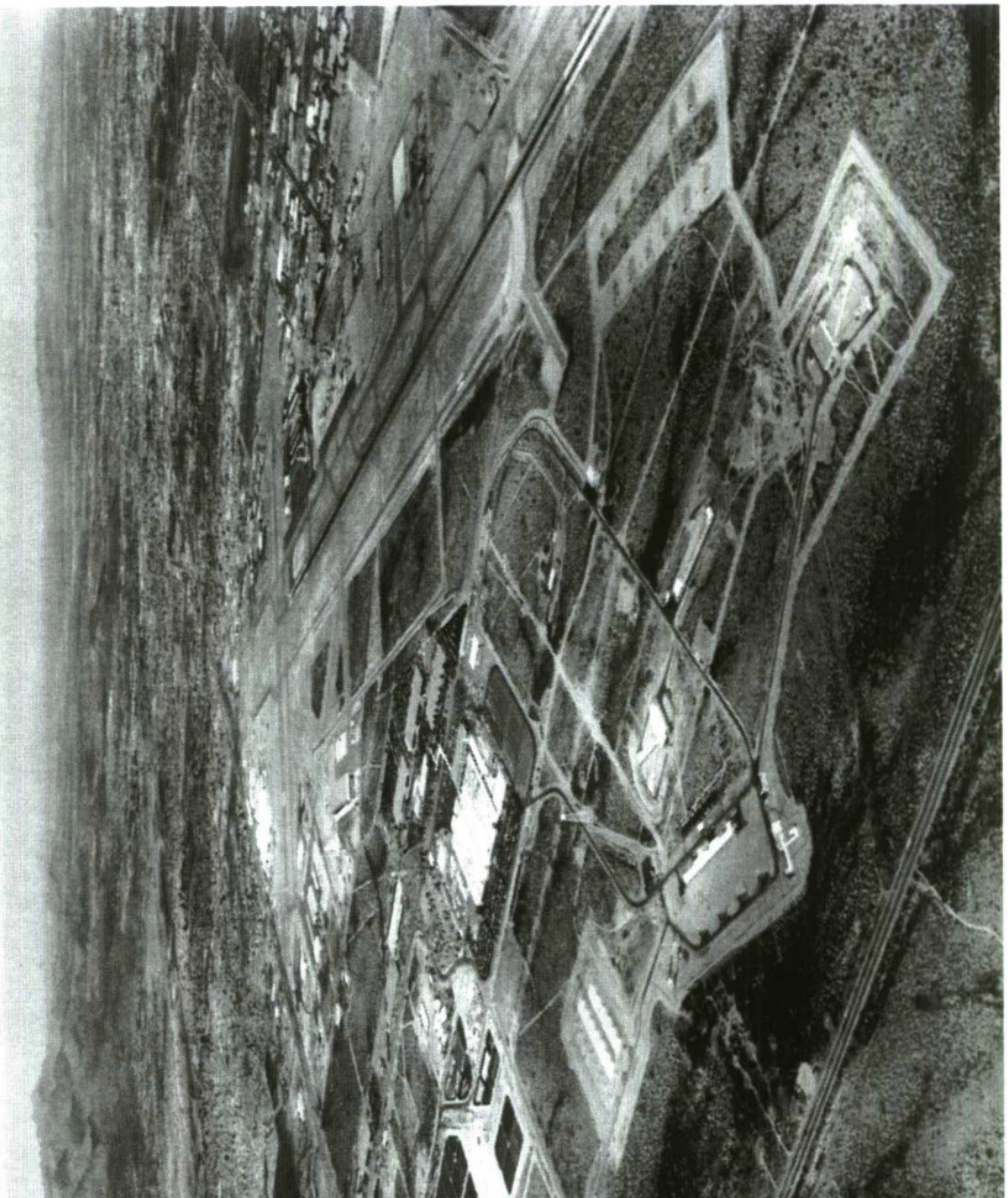

Plate 214: Aerial View of Air Force Plant 44, Tucson, Arizona, undated. Courtesy of Joseph Trnka.

munitions storage area. Hughes stored completed missiles in the munitions area, prior to delivery to the Air Force. As was the case for later missiles and bombs produced at AFP 44, Hughes did not conduct developmental or evaluation work for the Falcon at the plant. Instead, the company used the GOCO facilities entirely for manufacture and post-production quality assurance testing. Hughes assembled multiple, sequential versions of the Falcon at AFP 44, beginning with GAR (guided air rocket) -1 in the middle 1950s. Peak production for the Falcon occurred in 1957; manufacture of the Falcon series ended in 1963. Falcon modification programs continued at the plant until 1969. ADC fighter-interceptor planes carried the Falcon, including the F-86, F-89, F-100, F-102, F-106, and F-4.

While production of the Falcon missile was the main activity at AFP 44 from its opening in the early 1950s through the late 1960s, by the close of the plant's second decade Hughes sought and won additional missile manufacturing contracts for the GOCO site. Several of the follow-on contracts for AFP 44 were ones for Navy and Army weapons systems. As personnel completed Falcon modification projects at the plant during 1967-1969, Hughes transitioned to its next-era projects by handling another company's workload. In 1967, Hughes Aircraft Company became a second-source producer for the Navy's Walleye glide bomb, a munition developed and primarily manufactured (as of 1966) by Glenn L. Martin. Navy pilots guided the Walleye, AGM (air-to-ground missile) -62, to its target using a television link. Hughes manufactured the Walleye at AFP 44 into 1974. During the late 1960s also, Hughes—by this date formally the Hughes Missile Systems Company—also undertook production for the Army's TOW antitank missile (BGM [ballistic guided missile] –71). Hughes had initiated development of the TOW in 1965, with the first production delivery in 1970. TOW manufacture at AFP 44 continued past the end of the Cold War. Hughes additionally conducted the R&D, testing, and evaluation for its Phoenix air-to-air missile, a Navy munition, throughout the 1960s. Efforts on the Phoenix originated in 1960, with flight tests as of 1965. Production of the Phoenix at AFP 44 began in 1973. The final two missiles systems manufactured at the Tucson plant were the Air Force Maverick, the AGM-65, and the joint Air Force / Navy AMRAAM (AIM [air interceptor missile]-120). Production for the Maverick was underway at AFP 44 in 1968; for the AIM-120, in 1981. Hughes continued assembly and checkout of both weapons beyond 1991. The Air Force added facilities at AFP 44 during the first half of the 1970s (for the Walleye and Phoenix programs), with modest additions during the 1980s. Hughes adapted the facilities, as needed, for each successive munitions system in production. In the 1990s, Hughes Missile Systems became a part of Raytheon Corporation.

Key Associated Architects and Engineers

Architectural-engineering firms of national significance designing facilities for AFPs 4, 6, 42, and 44 included those below, with discussions found in Volume I or in other chapters of Volume II, as noted:

- The Austin Company, of Cleveland (Volume I, Part II);
- Holmes & Narver, of Los Angeles (Volume II, Chapter 4);
- Pereira & Luckman, of Los Angeles (Volume II, Chapter 3);
- Robert & Company, of Atlanta (Volume I, Part II);
- Peter Strobel, of New York (Volume II, Chapter 5); and,
- J. Gordon Turnbull, of Cleveland (Volume I, Part III).

[1] Bernard J. Termena, Layne B. Peiffer, and H.P. Carlin, *Logistics: An Illustrated History of AFLC and its Antecedents, 1921-1981* (Wright-Patterson Air Force Base: Office of History, Air Force Logistics Command, ca.1981), 134, 152.
[2] Philip Shiman, *Forging the Sword: Defense Production during the Cold War*, USACERL Special Report 97/77 (Champaign, Illinois: United States Army Construction Engineering Research Laboratories, July 1997), 15.

---

[3] Air Materiel Command (Frederick A. Alling, Ethel M. DeHaven, Helen Brents Joiner, and Clifford A. Morrison), *History of the Air Materiel Command 1 January – 30 June 1951*, volume 1, 265-267, with map.
[4] Joseph Trnka and William Manley, *Historic Building Inventory and Evaluation of Air Force Plant 4, Fort Worth, Texas* (Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, January 1997). Primary discussion for AFP 4 is summarized from this volume, with larger contextual background on the Air Force plant program given in Volume 1, Part II. Endnotes presented in Volume 1 are not repeated here.
[5] Robert Mueller, *Active Air Force Bases within the United States of America on 17 September 1982*, volume 1 in *Air Force Bases* (Washington, D.C.: Office of Air Force History, 1989), 66.
[6] David Donald (ed.), *World Aircraft* (London: Amber Books Ltd, 1990; reprinted in 2001), 452.
[7] Joseph Trnka and William Manley, *Historic Building Inventory and Evaluation of Air Force Plant 6, Marietta, Georgia* (Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, February 1997). Primary discussion for AFP 6 is summarized from this volume, with larger contextual background on the Air Force plant program given in Volume 1, Part II. Endnotes presented in Volume 1 are not repeated here.
[8] R.W. Stuck, "Huge Aircraft Assembly Plant Built at Marietta, Ga.," *Civil Engineering* 14, 3 (March 1944): 93-97.
[9] Mueller, *Active Air Force Bases*, 1989, 108.
[10] Lockheed-Georgia Company, "Nose Hangars No. 6, 7, 8, 9, 10, 11," 19 February 1963; ARMCO, "Shelter B-47 Nose Dock," 4 January 1955 (adaptation of ARMCO drawing 54-85E); Lockheed-Georgia Company, "Nose Hangars & Misc. Buildings Industrial Area," undated.
[11] Karen J. Weitze, *Cold War Infrastructure for Strategic Air Command: The Bomber Mission* (Sacramento: KEA Environmental, Inc., November 1999), 62-83.
[12] Stevens & Wilkinson, "Aircraft Shelter Lockheed Aircraft Corp Marietta, GA," 23 April 1956.
[13] Weitze, *Cold War Infrastructure for Strategic Air Command*, 1999, 59-62.
[14] "Nose Hangars No. 6, 7, 8, 9, 10, 11," 19 February 1963.
[15] Joseph Trnka, Laura Taylor Lambros, and Norman Rajotte, *Historic Building Inventory and Evaluation of Air Force Plant 42, Palmdale, California* (Colton, California: Earth Tech, Inc., and Research Management Consultants, Inc., for Aeronautical Systems Center, Air Force Materiel Command, March 1997). Primary discussion for AFP 42 is summarized from this volume, with larger contextual background on the Air Force plant program given in Volume 1, Part II. Endnotes presented in Volume 1 are not repeated here.
[16] Peter K. Mok, Chief Engineer, AFP 42, informal oral interview with Karen J. Weitze, 4 April 2000.
[17] *Ibid.*
[18] *Ibid.*
[19] Joseph Trnka, Mike Blackwell, and Norman Rajotte, *Historic Building Inventory and Evaluation of Air Force Plant 44, Tucson, Arizona* (Colton, California: Earth Tech, Inc., and Research Management Consultants, Inc., for Aeronautical Systems Center, Air Force Materiel Command, December 1996). Primary discussion for AFP 44 is summarized from this volume, with larger contextual background on the Air Force plant program given in Volume 1, Part II. Endnotes for specifics presented in Volume 1 are not repeated here.
[20] Karen J. Weitze, *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970*, Holloman Air Force Base Cultural Resources Publication No. 5 (El Paso: Geo-Marine, Inc., for Air Combat Command, November 1997), 25.

Bibliography

The bibliography is organized in the references-cited format commonly found in government documents, but is focused on pertinent Air Force and Army literature. It is intended to facilitate further research as a stand-alone tool, and to encourage Air Force cultural resource managers and military historians to retrieve information from multiple archival collections. First sources provided below are general military, and real property, in character. Second sources are Air Force and Army Air Forces in type, and are substantially archived at the Air Force Historical Research Agency, Maxwell Air Force Base, Montgomery, Alabama, and at the National Archives II in suburban Washington, D.C. Cited authors vary from specific military historians to the command / tiered units responsible (without the historians called out by name). When given, individual Air Force historians are cited in brackets for their command or unit, and thus alphabetized by their Air Force affiliation rather than by surname. Final sources included here are those that are available at the installation level, concentrating on engineering drawings and oral interviews of past personnel. The bibliography also includes the references pertinent to the plates, where those items are not called out in endnotes. Not found in the bibliography are history and engineering references of non-military type, as well as articles from engineering journals, newspapers and broad histories, and internet postings. These items appear in their complete citations in the chapter endnotes.

Particularly important to any analysis of Air Force historic real property are documents held at the Air Force Historical Research Agency at Maxwell Air Force Base. The Historical Research Agency serves as the primary repository for all Air Force records below the policy level and maintains truly excellent holdings. Bibliographic entries below include numeric coding specific to the Agency, to make any requests for the documents as efficient as possible. Researchers need to add the associated dates for each code—typically those included in the document title. Dates are given within the reference code where any possibility of confusion remains. If a volume number is included in the coding, this typically indicates a narrative (usually as volume 1) and appendices (volumes 2 forward). Sometimes, however, unusual situations occur. For the histories of Air Force civil engineering at the Headquarters level, such is the case. For these entries, volume number in the coding refers to the specific sequencing of the civil engineering (earlier, installations) directorate among that for other directorates (such as operations) within the volume series. One other confusing situation occurs with regards to volume numbering for documents at the Air Force Historical Research Agency. For some documents, the individual item has an alternate title and is a volume in another series. In these cases, when useful, the volume number of the series is included after the title, while the volume number given with the K coding usually refers to distinctions between narrative and appendices. The histories for the Cambridge Research Laboratories / Center are an excellent example of the "double" volume numbering. Both Air Defense Command and Strategic Air Command also have multiple special studies series, with separate volume numbering. When no volume number is given in the K coding, this typically indicates that there is only one volume. If appended documents exist in these instances, they are bound with the narrative history.

The system used at the Air Force Historical Research Agency is particularly critical to relocating documents. For Air Force Historical Research Agency sources, a researcher is encouraged to request materials by their "K" number. Without this information, search time can be lengthened considerably—especially in any request for specific test reports, memoranda, and letters. The K system is divided into sources before and after mid-1950, with those of July 1950 forward recorded with the "K," while those before this date have only a numeric sequence (K280.10-48 versus 280.10-47, for example). The system is generally consistent, but not absolute due to the sheer size of the Air Force Historical Research Agency collections.

Books and Documents: United States Department of Defense and Related

Brown, Kenneth and Peter Weiser (eds). *Ground Support Systems for Missiles and Space Vehicles.* New York: McGraw-Hill Book Company, Inc., 1961.

81st Congress. Chapter 766—1st Session, Public Law 415 [S. 1267]. 27 October 1949.

Fine, Lenore and Jesse A. Remington. *The Corps of Engineers: Construction in the United States*, volume in *United States Army in World War II The Technical Series.* Washington, D.C.: Office of the Chief of Military History, 1972.

Freeman, Eva C. (ed). *MIT Lincoln Laboratory: Technology in the National Interest.* Lexington, Massachusetts: Lincoln Laboratory, Massachusetts Institute of Technology, 1995.

Furman, Necah Stewart. *Sandia National Laboratories: The Postwar Decade.* Albuquerque: University of New Mexico, 1990.

Heflin, Woodford Agee (ed). *The United States Air Force Dictionary.* Princeton, New Jersey: D. Van Nostrand Company, Inc., ca.1954.

House of Representatives. *Subcommittee Hearings on H.R. 3434, to Promote the National Defense by Authorizing a Unitary Plan for the Construction of Transonic and Supersonic Wind-Tunnel Facilities and the Establishment of an Air Engineering Development Center*, Washington, D.C., 11 April 1949.

Johnson, Leland. *Sandia National Laboratories: A History of Exceptional Service in the National Interest.* Albuquerque: Sandia National Laboratories, 1997.

Joint Research and Development Board. Electronics Committee. Radar Panel. Subpanel on Aircraft Interception Direction. "Report of the Subpanel on Aircraft Interception Direction." Draft. September 1948. Air Force Historical Research Agency, Maxwell Air Force Base. 160.823-6 10 October 1948.

Neufeld, Michael J. *The Rocket and the Reich: Peenmünde and the Coming of the Ballistic Missile Age.* Cambridge, Massachusetts: Harvard University Press, 1995.

Office of the Secretary of Defense. Research and Development Task Force. *Edwards Air Force Base Data & Information.* 1950. History Office, Edwards Air Force Base.

Special Committee on A.E.D.C. Operation. *Report of the Special Committee on A.E.D.C. Operation* [*Markham Report*]. 26 April 1950. History Office, Arnold Engineering Development Center.

Tennessee Valley Authority. *Air Engineering Development Center Adaptability of Sites in the TVA Area.* Eight-page typescript with map. May 1949. History Office, Arnold Engineering Development Center.

Ullrich, Rebecca. *Tech Area II: A History, Contractor Report SAND98-1617.* Albuquerque: Ktech Corporation, for Sandia National Laboratories, July 1998.

Real Property Inventories and Contexts: United States Department of Defense

Bilderbach, Daniel R. and Michael S. Binder. *Early DoD-Sited Nuclear Warhead Infrastructure.* University of South Carolina Legacy Project. May 1999.

Carey, Fred, Ellen Ehrenhart, Barry Greenhouse, Harriet Kaplan, Darlene Roth, Eva Santorini, and Catherine Wilson-Martin. *Cold War Facility Survey and Report Robins Air Force Base.* Draft. Bethesda, Maryland: Potomac-Hudson Engineering, Inc., for Air Force Materiel Command, June 1999.

Cleveland, M. Todd and Jeffrey L. Holland. *Historic Buildings Survey Arnold Engineering Development Center.* Atlanta: TRC Garrow Associates, Inc., for Air Force Materiel Command, July 2000.

Cotterman, Cary D., Scott M. Hudlow, Linda Auten, Christopher O. Hurst, Dena S. Komporlides, and Susan L. Bupp. *Inventory and Evaluation of Selected Military Period Structures at South Base, Edwards Air Force Base, California*, volumes 1 and 2. San Bernardino, California: Tetra Tech, Inc., for Air Force Materiel Command, October 1997.

Dyson, Emma J.H., Dean A. Herrin, and Amy E. Slaton. *The Engineering of Flight: Aeronautical Engineering Facilities of Area B, Wright-Patterson Air Force Base, Ohio.* Washington, D.C.: National Park Service, for Air Force Materiel Command, 1993.

Earle, David D., Kelly A. Lark, Cole J. Parker, Margaret R. Ronning, and Jackson Underwood. *Overview of Historic Cultural Resources*, volume 2 of *Cultural Resources Overview and Management Plan for Edwards AFB, California.* Edwards Flight Test Center: Computer Sciences Corporation, for Air Force Materiel Command, March 1998.

Hampton, Roy A., Stanley J. Popovich, Donald M. Durst, Charissa Y. Wang, and Cindy Hassan. *Updated Building Evaluations for Historic Significance at Wright-Patterson Air Force Base.* Columbus and Cincinnati: Hardlines: Design & Delineation and International Technology Corporation, for Air Force Materiel Command, 13 October 1998.

Hardlines: Design & Delineation. *Historic Context Report for Wright-Patterson Air Force Base.* Columbus, Ohio: Hardlines: Design & Delineation, for Air Force Materiel Command, January 1999.

Hay, Conran A., Wendy Zug-Gilbert, Margaret M.M. Pickart, and Douglas Dinsmore. *Documenting the Cold War Significance of Wright Laboratory Facilities Wright-Patterson Air Force Base.* Columbus, Ohio: Archaeological and Historical Consultants, Inc., for Air Force Materiel Command, February 1996.

Hudlow, Scott M. *Phase II Architectural Evaluation for the Jet Propulsion Laboratory Closure Project, Edwards AFB, Kern County, California.* Edwards Flight Test Center: Computer Sciences Corporation, for Air Force Materiel Command, June 1995.

Hudlow, Scott M., Matt Bishoff, Jan Lawson, and John Z. Terreo. *Cultural Resource Evaluation of the North Base Complex (The Muroc Flight Test Base and the Rocket Sled Test Track), Edwards AFB, Kern County, California* volume 1. Edwards Flight Test Center: Computer Sciences Corporation, for Air Force Materiel Command, May 1995.

Hurst, Christopher, Linda Auten, Susan L. Bupp, Cary Cotterman, and Dena S. Komporlides. *Historical Overview of Phillips Laboratory Operating Location at Edwards Air Force Base, California*. San Bernardino, California: Tetra Tech, Inc., for Air Force Materiel Command, July 1997.

Johnson, Charles M. *Evaluation Report Historical Assessment Tinker AFB Oklahoma City, Oklahoma Contract No. F34650-93-D-0109, Order 5020*. Del City, Oklahoma: Woodward-Clyde Federal Services, for Air Force Materiel Command, August 1996.

Johnson, Charles M. *Nomination Package for Historic District Eligible for the National Register of Historic Places for Tinker AFB Oklahoma City, Oklahoma Contract No. F34650-93-D-0109, Order 5006*. Del City, Oklahoma: Woodward-Clyde Federal Services, for Air Force Materiel Command, July 1995.

Johnson, Charles M. *Nomination Packages for Buildings 230, 240 and 4029 Tinker AFB Oklahoma City, Oklahoma Contract No. F34650-93-D-1019, Order 5020*. Del City, Oklahoma: Woodward-Clyde Federal Services, for Air Force Materiel Command, September 1996.

Jones & Stokes Associates, Inc. *Cultural Resources Management Plan for McClellan Air Force Base*. Sacramento: Jones & Stokes Associates, Inc., for Air Force Materiel Command, 31 January 1997.

Kiersteadt, Matt. "Inventory and Evaluation for the Draper Laboratory (MIT Hangar)." Draft. Pawtucket, Rhode Island: Public Archaeology Laboratory, for Air Force Materiel Command, July 2001.

Komporlides, Dena S., Linda Auten, Christopher O. Hurst, Cary D. Cotterman, and Susan L. Bupp. *Inventory and Evaluation of Selected Military Period Structures at Main Base, Edwards Air Force Base, California*, volumes 1 and 2. San Bernardino, California: Tetra Tech, Inc., for Air Force Materiel Command, July 1997.

Komporlides, Dena S., Christopher O. Hurst, Linda Auten, Carey D. Cotterman, and Susan L. Bupp. *Historical Overview of the National Advisory Committee for Aeronautics (NACA) and the National Aeronautics and Space Administration (NASA) at Edwards Air Force Base, California*. San Bernardino: Tetra Tech, Inc., for Air Force Materiel Command, February 1996.

Lassell, Susan, Shahira Ashkar, and Dana McGowan. *Phase II Cultural Resource Evaluation of the Air Force Research laboratory at Edwards AFB, California*. Sacramento: Jones & Stokes Associates, Inc., for Air Force Materiel Command, September 1998.

LEC Environmental Consultants, Inc. *Comprehensive Ecological Analysis Hanscom Air Force Base*. Cambridge, Massachusetts: The Boston Partnership, Inc., for Air Force Materiel Command, December 1995. Revised August 1997.

Lonnquest, John C. and David F. Winkler. *To Defend and Deter: The Legacy of the United States Cold War Missile Program*. USACERL Special Report 97/01. Champaign, Illinois: United States Army Construction and Engineering Research Laboratories, November 1996.

Lu Engineers. *Cold War Historic Building Survey Rome Research Site*. Penfield, New York: Lu Engineers, for Air Force Materiel Command, November 1999.

Mattson, Wayne O. and Martyn D. Tagg. *"We Develop Missiles, Not Air!": The Legacy of Early Missile, Rocket, Instrumentation, and Aeromedical Research Development at Holloman Air Force Base*. Holloman Air Force Base Cultural Resources Publication No. 2. Holloman Air Force Base: Air Combat Command, June 1995.

McChristian, Douglas C. and Thomas G. Alexander. *From Arms to Aircraft: A Brief History of Hill Air Force Base*. Denver: National Park Service, for Air Force Materiel Command, September 1996.

McChristian, Douglas C. and Jerome A. Greene. *Arsenal of the Cold War: A Survey of Potentially Significant Facilities on Property Administered by Hill Air Force Base, Utah*. Denver: National Park Service, for Air Force Materiel Command, December 1999.

McGowan, Dana, Susan Lassell, and Shahira Ashkar. *Phase II Cultural Resource Evaluation of the South Base Sled Track at Edwards AFB, Kern and Los Angeles Counties, California*. Sacramento: Jones & Stokes Associates, Inc., for Air Force Materiel Command, May 1998.

Patterson, Patience Elizabeth, David P. Staley, and Katherine J. Roxlau. *A Baseline Inventory of Cold War Material Culture at Whiteman Air Force Base*, volume II-27 of *A Systemic Study of Air Combat Command Cold War Material Culture*. Albuquerque: Mariah Associates, Inc., for Air Combat Command, August 1997.

Peter, Duane E., Maynard B. Cliff, Joe Freeman, and Kimberly L. Kane. *Brooks Air Force Base Historic Preservation Plan*. Plano, Texas: Geo-Marine, Inc., for Air Force Materiel Command, March 1995.

Puckett, Heather (Earth Tech, Inc.) and Janet Ostashay (Planning Consultants Research). *Historic Building Inventory and Evaluation of Cold War-Era Buildings at Brooks Air Force Base*. Colton, California: Earth Tech, Inc., and Planning Consultants Research, for the Air Force Center for Environmental Excellence, October 1998.

Puckett, Heather and Andrea Urbas. *Cold War Historic Building Inventory and Evaluation Security Hill, Kelly Air Force Base*. Colton, California: Earth Tech, Inc., for the Air Intelligence Agency, May 1998.

Science Applications International Corporation (SAIC). *Phase I Historic Building Survey, Arnold Engineering Development Center*. Oak Ridge, Tennessee: Science Applications International Corporation, for Air Force Materiel Command, May 1977.

Shiman, Philip. *Forging the Sword: Defense Production during the Cold War*. USACERL Special Report 97/77. Champaign, Illinois: United States Army Construction Engineering Research Laboratories, July 1997.

Tetra Tech, Inc., and Thomason and Associates. *Historic Structures Survey Griffiss Air Force Base*. San Bernardino, California, and Nashville, Tennessee: Tetra Tech, Inc., for Air Force Materiel Command through the Air Force Center for Environmental Excellence, October 1995.

Trnka, Joseph, Mike Blackwell, and Norman Rajotte. *Historic Building Inventory and Evaluation of Air Force Plant 44, Tucson, Arizona.* Colton, California: Earth Tech, Inc., and Research Management Consultants, Inc., for Aeronautical Systems Center, Air Force Materiel Command, December 1996.

Trnka, Joseph, Laura Taylor Lambros, and Norman Rajotte. *Historic Building Inventory and Evaluation of Air Force Plant 42, Palmdale, California.* Colton, California, and Golden, Colorado: Earth Tech, Inc., and Research Management Consultants, Inc., for Aeronautical Systems Center, Air Force Materiel Command, March 1997.

Trnka, Joseph and William Manley. *Historic Building Inventory and Evaluation of Air Force Plant 3, Tulsa, Oklahoma.* Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, November 1996.

Trnka, Joseph and William Manley. *Historic Building Inventory and Evaluation Air Force Plant 4, Fort Worth, Texas.* Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, January 1997.

Trnka, Joseph and William Manley. *Historic Building Inventory and Evaluation of Air Force Plant 6, Marietta, Georgia.* Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, February 1997.

Trnka, Joseph and Heather Puckett (Earth Tech, Inc.), and, Charles Arthur and Mary Sayers (Woodward-Clyde). *Historic Building Inventory and Evaluation Griffiss Air Force Base*, volumes 1 and 2. Draft. Colton, California: Earth Tech, Inc., for Air Combat Command, July 1998.

Trnka, Joseph, Terri Wessel, and William Manley. *Historic Building Inventory and Evaluation of Air Force Plant PJKS, Jefferson County, Colorado.* Colton, California: Earth Tech, Inc., and William Manley Consulting, for Aeronautical Systems Center, Air Force Materiel Command, February 1997.

Tuttle, Christine. *Historic Building Inventory and Evaluation Kirtland Air Force Base*. Kirtland Air Force Base: 377th Air Base Wing Environmental Management Division, April 1999.

Urbas, Andrea and Paige Peyton. *Brooks AFB, Texas: Man-in-Space Era Historic Building Inventory and Evaluation.* Draft. Colton, California: Earth Tech, Inc., for the Air Force Center for Environmental Excellence, February 2001. A later version of the draft exists from May 2001.

Verhaaren, Bruce T. *Cold War Resources*, part II of *A Cultural Resources Inventory of the Manzano Storage Area.* Lakewood, Colorado: Argonne National Laboratory, for Air Force Materiel Command, 22 July 1998.

Webster, Julie L., Michael A. Pedrotty, and Aaron R. Chmiel. *Historical and Architectural Overview of Military Aircraft Hangars: A General History, Thematic Typology, and Inventory of Aircraft Hangars and Associated Buildings on Department of Defense Installations.* USACERL Technical Report 96. Draft. Champaign, Illinois: United States Army Construction and Engineering Laboratories, March 1996.

Weitze, Karen, J. *Aeromedical Evacuation Annotated Bibliography*. Colton, California: Earth Tech, Inc., for the Air Force Center for Environmental Excellence, November 1994.

Weitze, Karen J. *Aurora Pulsed Radiation Simulator Historic American Engineering Record No. MD-144*. Plano, Texas: Geo-Marine, Inc., for Army Materiel Command, 1996.

Weitze, Karen J. *Cold War Infrastructure for Air Defense: The Fighter and Command Missions*. Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999.

Weitze, Karen J. *Cold War Infrastructure for Strategic Air Command: The Bomber Mission*. Sacramento: KEA Environmental, Inc., for Air Combat Command, November 1999.

Weitze, Karen J. *Detroit Arsenal Cultural Resources Management Plan*. Plano, Texas: Geo-Marine, Inc., for Army Materiel Command, October 1996.

Weitze, Karen, J. *Eglin Air Force Base, 1931-1991: Installation Buildup for Research, Test, Evaluation, and Training*. San Diego: KEA Environmental, Inc., for Air Force Materiel Command, January 2001.

Weitze, Karen J. *Guided Missiles at Holloman Air Force Base: Test Programs of the United States Air Force in Southern New Mexico, 1947-1970*. Holloman Air Force Base Cultural Resources Publication No. 5. El Paso: Geo-Marine, Inc., for Air Combat Command, November 1997.

Weitze, Karen J. *Historic Architectural and Engineering Survey Report Atlas Abres-A*. Austin, Texas: Dames & Moore, for Air Force Space Command, 26 March 1993.

Weitze, Karen J. *Inventory of Cold War Properties: Andrews, Charleston, Dover, Grand Forks, McChord, Scott, and Travis Air Force Bases*. Seven Volumes. Plano, Texas: Geo-Marine, Inc., for Air Mobility Command, October 1996.

Weitze, Karen J. *National Register of Historic Places Evaluation Peacekeeper Rail Garrison Complex Vandenberg Air Force Base*. Austin, Texas: Dames & Moore, Inc., for Air Force Materiel Command, April 1994.

Weitze, Karen J. *PAVE PAWS Beale Air Force Base Historic Evaluation and Context*. Sacramento: KEA Environmental, Inc., for Air Combat Command, February 1999.

Weitze, Karen J. *Request for Determination of Eligibility SLC-2W and SLC-2 Blockhouse Structures Vandenberg Air Force Base*. Austin, Texas: Dames & Moore, for Air Force Space Command, 2 October 1991.

Weitze, Karen J., James H. Cleland, Carrie Gregory, and Lori Lilburn. *Historical Assessment of Marshall Space Flight Center*. Draft. San Diego: EDAW, Inc., for the National Aeronautics and Space Administration, May 2002. Final version, March 2003.

Weitze, Karen J. and Christy Dolan. *Historic American Buildings Survey for the Marine Corps Air Station, Tustin, California*, HABS No. CA-2707. San Diego: KEA Environmental, Inc., January 2000.

Weitze, Karen J., Carrie Gregory, and Lori Lilburn. *Eglin Air Force Base Inventory of Historic Properties 2001-2003. Part III*. Draft. San Diego: EDAW, Inc., for Air Force Materiel Command, February 2003.

Weitze, Karen J., Carrie Gregory, Lori Lilburn, and Angie Gustafson. *Eglin Air Force Base Inventory of Historic Properties 2001-2003. Part I.* Draft. San Diego: EDAW, Inc., for Air Force Materiel Command, February 2002.

Weitze, Karen J., Lori Lilburn, Christy Dolan, and Angie Gustafson. *Eglin Air Force Base Inventory of Historic Properties FY 2000*, volumes 1-2. San Diego: EDAW, Inc., for Air Force Materiel Command, September 2001.

Winkler, David F. *Searching the Skies: The Legacy of the United States Cold War Defense Radar Program.* Champaign, Illinois: United States Army Construction Engineering Research Laboratories, for Air Combat Command, June 1997.

Woodward-Clyde Federal Services. *Tinker AFB Cultural Resource Management Plan.* Del City, Oklahoma: Woodward-Clyde Federal Services, for Air Force Materiel Command, January 2000.

York, Andrew L., Tanya Wahoff, and Michael Corbett. *Cultural Resource Investigations at Area P Housing Complex and Adjacent Sites Edwards Air Force Base, California.* San Diego: Dames & Moore, Inc., for Air Force Materiel Command, November 1997.

Documents: United States Army Air Forces and United States Air Force

Alberts, Don E. and Allan E. Putnam. *A History of Kirtland Air Force Base 1928 – 1982.* Kirtland Air Force Base: Air Force Test and Evaluation Center and the 1606th Air Base Wing, June 1982.

Alcott, Edward B. *Contributions of the Human Systems Center at Brooks AFB to Air Force History.* Typescript of a draft essay composed for the History Office, Headquarters United States Air Force. 21 December 1995.

Alcott, Edward B., Dick Emmons, Ann Hussey, Thomas Manning, Pat Parrish, and Edgar Sneed. *A History of Military Aviation in San Antonio.* San Antonio: United States Air Force, September 1996.

Alcott, Edward B. and SMSgt. Robert C. Williford. *Aerospace Medical Division: Twenty-Five Years of Excellence 1961-1986.* Brooks Air Force Base: History Office, Aerospace Medical Division, Air Force Systems Command, 1986.

Aldridge, James F. "A Historical Overview of the Mission and Organization of the Wright Laboratory 1917-1993." Draft. Wright-Patterson Air Force Base: History Office, Aeronautical Systems Center, Air Force Materiel Command, November 1994.

Aldridge, James F. "Fifty Years of Aeronautical Research, Development, and Systems Acquisition at Wright-Patterson Air Force Base." Draft contribution on behalf of the History Office, Aeronautical Systems Center, for a proposed Headquarters United States Air Force 50th anniversary book on United States Air Force R&D.

Aldridge, James F., Dean C. Kallander, Paul C. Ferguson, Laura N. Romesburg, and Henry M. Narducci. *Against the Wind: 90 Years of Flight Test in the Miami Valley*. Wright-Patterson Air Force Base: History Office, Aeronautical Systems Center, Air Force Materiel Command, 1994.

"Aluminum Housing at Air Installations." Memorandum for Deputy Chief of Staff, Materiel, stamped "Directorate of Installations File." 16 June 1948. Record Group 341, Entry 494, Box 6, File "Housing 1948," 2 of 2. National Archives II, Maryland.

Brown, C. Pratt. Brigadier General, Acting Assistant Chief of Staff, Installations. "Mitchell Mobilhangar." Undated memorandum of 1954. Record Group 341, Entry 494, Box 494, File "Hangars 1954." National Archives II, Maryland.

"Building 375." Vertical file of clippings and typescripts for planning, construction, and use. History Office, Kelly Air Force Base. Location of the files after base realignment in July 2001 is anticipated as Lackland Air Force Base.

Casey, Dennis F. and Gabriel G. Marshall. *A Continuing Legacy: USAFSS to AIA 1948-1997*. Kelly Air Force Base: History Office, Air Intelligence Agency, 1997.

Clark, W.T. Letter. 21 December 1948. Record Group 341, Entry 494, Box 6, File "Housing 1948," 1 of 2. National Archives II, Maryland.

Coleman Engineering Company, Inc. *The Fact Book of Project SMART*. ca.1958. History Office, Aeronautical Systems Center, Air Force Materiel Command, Wright-Patterson Air Force Base.

Crain, Charles E. Jr., and Robert S. Giles (eds). *A Pictorial History of Kelly Air Force Base*. Kelly Air Force Base: Office of History, San Antonio Air Logistics Center, ca.1981.

Cully, George. History Office, Aeronautical Systems Center, Air Force Materiel Command, Wright-Patterson Air Force Base. 55-page typescript list of numbered MX projects, MX-1 to MX-2276. Work in progress, 21 November 2000.

Curtis, Richard H. Deputy Chief of Staff, Materiel, Air Force Cambridge Research Center, to the Commander, Air Research and Development Command, Baltimore. "Clearance Criteria for Double Cantilever Hangar." Memorandum. 4 August 1954. Record Group 341, Entry 494, Box 494, File "Hangars 1954." National Archives II, Maryland.

Del Papa, E. Michael *A Historical Chronology of the Electronic Systems Division 1947-1990*. Hanscom Air Force Base: History Office, Electronic Systems Division, October 1991.

"Facilities of WADC 1958 (1942-1959)." Box "Organizations / WADC," Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Air Force Materiel Command, Wright-Patterson Air Force Base.

Garcia, Mary J.C. *An Annotated Bibliography of Civil Engineering Research*. Technical Report No. AFWL-TR-69-179. February 1970. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145-4.

Gorn, Michael H. *Vulcan's Forge: The Making of An Air Force Command for Weapons Acquisition (1950-1985).* Andrews Air Force Base: Office of History, Headquarters, Air Force Systems Command, second printing, October 1986. Air Force Historical Research Agency, Maxwell Air Force Base. K243.04-55 volumes 1 and 2.

Greenwood, John T. *Space and Missile Systems Organization: A Chronology, 1954-1979.* Los Angeles Air Force Station: Space Division History Office, ca.1984.

Grindstaff, Charles W. *War Baby of the South 1940-1945: Robins Field, Georgia.* Robins Air Force Base: Office of History, Air Force Logistics Command, September 1988.

Hanley, Timothy C. and Harry N. Waldron. *Historical Overview Space & Missile Systems Center 1954-1995.* Los Angeles Air Force Base: History Office, Space & Missile Systems Center, April 1996. Reprinted with changes, June 1997.

Head, William P. Diane H. Truluck, Dean Corey, Christine McLeod, and Richard W. Iobst. *Time Capsule: A Chronology of the Role of the Warner Robins Air Logistics Center and Robins Air Force Base, Georgia, in World History, 1935-1995.* Robins Air Force Base: Office of History, Air Force Materiel Command, Fall 1996.

Hibbard, Charles G, Susan Weathers, and David Kendziora. *History of Hill Air Force Base.* Hill Air Force Base: History Office, Ogden Air Logistics Center, 1988.

Hussey, Ann K. *The History of Aircraft Maintenance at Kelly Air Force Base.* Kelly Air Force Base: Office of History, San Antonio Air Logistics Center, ca.1998.

Jensen, Edna. *History of USAF Participation in Project Paperclip September 1946 – April 1948 Volume II (Exploitation of German Scientists)*, Study No. 215. Wright-Patterson Air Force Base: Historical Office, Air Materiel Command, November 1948. History Office, Air Force Materiel Command, Wright-Patterson Air Force Base.

Jones, Kathi R. *A Brief History of Kelly Air Force Base*, SA-ALC Pamphlet 84-1. Kelly Air Force Base: Office of History, San Antonio Air Logistics Center, versions of October 1995 and June 1999.

Kellex Corporation. *Study of Instrumentation and Facilities for the Air Materiel Armament Test Center.* Final Engineering Report for Job-30, Contract AF 33(038)13892. New York: Kellex Corporation, 26 December 1950. Air Force Historical Research Agency, Maxwell Air Force Base. K215.1504-1 26 June 1950.

Lang, J.D. Directorate of Installations, United States Air Force. "Procurement of Prefabricated Houses." Memorandum. 16 December 1949. Record Group 341, Entry 494, Box 59, File "Housing Oct-Dec 1949." National Archives II, Maryland.

LeMay, Curtis E. "Use of Lustron Prefabricated Houses to Reduce Fire Hazard to Strategic Air Command Families." Memorandum to the Chief of Staff, United States Air Force. 10 May 1949. Record Group 341, Entry 494, Box 59, File "Housing June-Sept 1949," 1 of 2. National Archives II, Maryland.

Liebowitz, Ruth P. *Air Force Geophysics: Contributions to Defense and to the Nation, 1945-1995*, PL-TR-97-2034, Special Report No. 280. Hanscom Air Force Base: Geophysics Directorate, 8 April 1997.

Liebowitz, Ruth P. *The Electronic Systems Center 1991- 1996 An Overview History*. Hanscom Air Force Base: History Office, Electronic Systems Center, April 1999.

Liebowitz, Ruth P. and Paul A. Maria. *A Historical Chronology of Hanscom Air Force Base 1941-1997*. Hanscom Air Force Base: History Office, Electronics Systems Center, November 1997.

Marshall, Stewart A. J. Colonel, Chief, Architectural Services Branch, Architectural & Engineering Division, Directorate of Installations. "Double Cantilever Hangars." Memorandum to the Director, Legislation and Liaison, Director of Installations, Deputy Chief of Staff / Operations. 16 September 1952. Record Group 341, Entry 494, Box 284, File "Hangars 1952." National Archives II, Maryland.

McMullen, Richard F. Aerospace Defense Command History Office. *An Overview of Air Defense Command Weapons 1946-1972*. ADC Historical Study No. 39. 1973. Air Force Historical Research Agency, Maxwell Air Force Base. K410.041-39.

Miller, Maurice A. (ed). *McClellan Air Force Base 1936-1982*. McClellan Air Force Base: Office of History, Sacramento Air Logistics Center, December 1982.

Montoya, Juan and Ann Krueger Hussey. *A Brief History of Historical Sites and Structures on Kelly Air Force Base*. Kelly Air Force Base: Office of History, San Antonio Air Logistics Center, April 1993.

Moulton, Ralph R., Lieutenant Colonel, Assistant to the Chief, Air Installations, Headquarters Air Materiel Command. "Status of Architect-Engineer Contracts." Memorandum to the Director of Installations, Headquarters United States Air Force. 26 January 1953. Record Group 341, Entry 494, Box 381, File "Architect-Engineer 1953." National Archives II, Maryland.

Mueller, Robert. *Active Air Force Bases Within the United States of America on 17 September 1982*, volume 1 of *Air Force Bases*. Washington, D.C.: Office of Air Force History, 1989.

Narducci, Henry M. *A Century of Flight: The Evolution of Wright-Patterson Air Force Base*. Wright-Patterson Air Force Base: 88th Air Base Wing, Aeronautical Systems Center, Air Force Materiel Command, August 1999.

Neufeld, Jacob. *The Development of Ballistic Missiles in the United States Air Force 1945-1960*. Washington, D.C.: Office of Air Force History, 1990.

"New Warehouse Contract Awarded: Work to Start," *Tinker Take Off*. 5 November 1954.

North American Rockwell (Columbus Division). *Underbrush Simulated Test Complex Eglin AFB Reconnaissance System Test Planning Guide*. 31 July 1970. History Office, Air Force Research Laboratory, Rome Research Site, New York.

Oder, Barron K., Major Laurel Burnett, and Captain Rhonda Toba. *Phillips Laboratory: Its Origins and Chronology 13 December 1990 – 30 October 1997*. Kirtland Air Force Base: History Office, Phillips Research Site, July 1998.

Office Chief of Engineers. "Prefabricated Housing for Use Overseas." Memorandum to the Chief of Staff, United States Air Force, Installations Engineering Division. 18 August 1948. Record Group 341, Entry 494, Box 6, File "Housing 1948," 2 of 2. National Archives II, Maryland.

Patchin, Mr. to W.L. Foster. Information Request and Response. Tinker Air Force Base. 14 and 19 June 1956. History Office, Tinker Air Force Base.

Peebles, Curtis. *High Frontier: The U.S. Air Force and the Military Space Program.* Washington, D.C.: Air Force History and Museums Program, 1997.

Reise, Jack *Tinker Air Force Base: A Pictorial History.* Tinker Air Force Base: Air Force Logistics Command, 1983.

"Ribbon Cutting Ceremony on the SNRS PRAM Project." Executive Summary, Staff Summary Sheet. 29 November 1989. File "25-4-1 X-ray Inspection," History Office, McClellan Air Force Base. Location after base closure, unknown.

Rice, Helen. *History of Ogden Air Materiel Area Hill Air Force Base 1934-1960*, volume 1. Hill Air Force Base: Air Force Logistics Command, March 1963.

Sacramento Air Logistics Center. *Technology Profile NDI*, SM-ALC-MCAFBP 66-38, 1 April 1985. History Office, McClellan Air Force Base. Location after base closure, unknown.

Schaffel, Kenneth. *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense 1945-1960.* Washington, D.C.: Office of Air Force History, 1991.

Schill, Dan. "Building 230: Aircraft Maintenance to AWACS," *Tinker Take Off.* 6 March 1998. History Office, Tinker Air Force Base.

Schill, Dan. "The Early Years of Building 3001." Draft for *Tinker Take Off* article, file "Building 3001," 16 July 1999. History Office, Tinker Air Force Base.

Schill, Dan. "Supply Warehouse Opens in 1954," *Tinker Take Off.* 4 December 1998. History Office, Tinker Air Force Base.

Schill, Dan. "Years of Expansion Make Up Bldg. 201 History," *Tinker Take Off.* 3 September 1999. History Office, Tinker Air Force Base.

Shaw, Frederick J. Jr. and Timothy Warnock. *The Cold War and Beyond: Chronology of the United States Air Force, 1947-1997.* Washington, D.C.: Air Force History Office and Museums Program in association with Air University Press, 1997.

Smith, John Q. and David A. Byrd. *Forty Years of Research and Development at Griffiss Air Force Base June 1951 – June 1991*, RL-TR-92-45 In-House Report. Griffiss Air Force Base: Air Force Systems Command, ca.1991-1992.

Stephens, Paul W. Colonel, Deputy Chief, Air Installations Division, Air Materiel Command, Headquarters, Wright-Patterson Air Force Base. "Status of Architect-Engineer Contracts." Memorandum to the Director of Installations, Headquarters USAF. 10 September 1952. Record Group 341, Entry 494, Box 280, File "Contracts August-December 1952." National Archives II, Maryland.

Tagg, Lori S. *On the Front Line of R&D: Wright-Patterson Air Force Base in the Korean War, 1950-1953*. Wright-Patterson Air Force Base: History Office, Aeronautical Systems Center, Air Force Materiel Command, 2001.

Termena, Bernard J., Layne B. Peiffer, and H.P. Carlin. *Logistics: An Illustrated History of AFLC and Its Antecedents, 1921-1981*. Wright-Patterson Air Force Base: Office of History, Air Force Logistics Command, ca.1981.

Thompson, Thomas W. *RADC History Highlights 1951-1986*. Griffiss Air Force Base: Air Force Systems Command, 1986.

Thompson, Thomas W. "Rome Laboratory Narrative History." Typescript draft essay submitted to the History Office, Headquarters United States Air Force, 17 January 1996.

United States Air Force. *General Outline Specifications for Standard Air Force Buildings*. 1952. Air University, Maxwell Air Force Base.

United States Air Force. 552nd AEW&C Wing Information Office. "Air Defense and the 552nd AEW&C Wing." Four-page typescript of 19 May 1972. History Office, McClellan Air Force Base. Location after base closure, unknown.

United States Air Force. Air Defense Command. *4620th Air Defense Wing (Experimental SAGE) 1 June 1955 – 30 June 1958*. Air Force Historical Research Agency, Maxwell Air Force Base. K-WG-4620-HI.

United States Air Force. Air Defense Command. *History of the 27th Air Division (Defense) 1 April – 30 June 1951*. Air Force Historical Research Agency, Maxwell Air Force Base. K-DIV-27-HI.

United States Air Force. Air Defense Command. *History of the 58th Air Division (Defense) 8 September 1955 – 30 June 1956*. Air Force Historical Research Agency, Maxwell Air Force Base. K-DIV-58-HI.

United States Air Force. Air Defense Command and Lincoln Laboratory. *Operational Plan Semiautomatic Ground Environment System for Air Defense (Formerly Designated the Transition System)*, 7 March 1955. Air Force Historical Research Agency, Maxwell Air Force Base. K410.317-1.

United States Air Force. Air Force Logistics Command. Oklahoma City Air Materiel Area. *History Oklahoma City Air Materiel Area 1 July 1960 – 30 June 1961*, Installment 29, Part 1. History Office, Tinker Air Force Base.

United States Air Force. Air Force Logistics Command. Oklahoma City Air Materiel Area. *History of the Oklahoma City Air Materiel Area 1 July 1961 – 30 June 1962*, volume 1. History Office, Tinker Air Force Base.

United States Air Force. Air Force Logistics Command. Warner Robins Air Materiel Area. *History of the Warner Robins Air Materiel Area 1 July 1960 – 30 June 1961*. History Office, Robins Air Force Base.

United States Air Force. Air Force Logistics Command. Warner Robins Air Materiel Area. [Robert W. Barnwell]. *History of the Warner Robins Air Materiel Area 1 July 1961 – 30 June 1962*. History Office, Robins Air Force Base.

United States Air Force. Air Force Materiel Command. "History of the F-111." One-page typescript, undated. History Office, McClellan Air Force Base. Location after base closure, unknown.

United States Air Force. Air Force Materiel Command. *Phillips Laboratory Facilities*, Phillips Laboratory History Office Pamphlet Series, Number 5. Kirtland Air Force Base: History Office, Phillips Laboratory, ca.1996.

United States Air Force. Air Force Materiel Command. Aeronautical Systems Center. History Office. *Birthplace, Home and Future of Aerospace: The Evolution of Aeronautical Development at the Aeronautical Systems Center*. Wright-Patterson Air Force Base: Aeronautical Systems Center, Air Force Materiel Command, 1999.

United States Air Force. Air Force Materiel Command. Aeronautical Systems Center. History Office. *An Historic Tour of Wright-Patterson Air Force Base*. Wright-Patterson Air Force Base: Aeronautical Systems Center, Air Force Materiel Command, 1995.

United States Air Force. Air Force Materiel Command. Air Force Development Test Center. 46th Test Wing. *Land Test Areas*, volume 2 of *AFDTC Technical Facilities*, July 1996. Courtesy of Eglin Air Force Base.

United States Air Force. Air Force Materiel Command. Arnold Engineering Development Center. Office of Public Affairs. *AEDC: Aeropropulsion Systems Test Facility (ASTF)*, April 1998. Public Affairs Office, Arnold Air Force Base.

United States Air Force. Air Force Materiel Command. Arnold Engineering Development Center. Office of Public Affairs. *AEDC: Engine Test Facility (ETF)*, April 1998. Public Affairs Office, Arnold Air Force Base.

United States Air Force. Air Force Materiel Command. Arnold Engineering Development Center. Office of Public Affairs. *AEDC: Large Rocket Test Facility J-6*, August 1996. Public Affairs Office, Arnold Air Force Base.

United States Air Force. Air Force Materiel Command. Arnold Engineering Development Center. Office of Public Affairs. *AEDC: Von Karman Gas Dynamics Facility (VKF)*, April 1998. Public Affairs Office, Arnold Air Force Base.

United States Air Force. Air Force Materiel Command. Arnold Engineering Development Center. Office of Public Affairs. *AEDC Test Highlights: Space Environment Simulation Capabilities*, 1998. Public Affairs Office, Arnold Air Force Base.

United States Air Force. Air Force Materiel Command. Arnold Engineering Development Center. Office of Public Affairs. *Arnold Engineering Development Center (AEDC)*, April 1998. Public Affairs Office, Arnold Air Force Base.

United States Air Force. Air Force Systems Command. *50 Years of Excellence Griffiss Air Force Base*, ca.1992. History Office, Air Force Research Laboratory, Rome, New York.

United States Air Force. Air Force Systems Command. *History of Air Force Systems Command 1 July 1969 – 30 June 1970*. Air Force Historical Research Agency, Maxwell Air Force Agency. K243.01 volume 1.

United States Air Force. Air Force Systems Command. Aerospace Medical Division. *History of the Aerospace Medical Division 1 July 1967 – 30 June 1968*. Air Force Historical Research Agency, Maxwell Air Force Agency. K237.01 volumes 1 and 2.

United States Air Force. Air Force Systems Command. Aerospace Medical Division. *History of the Aerospace Medical Division 1 July 1968 – 30 June 1969*. Air Force Historical Research Agency, Maxwell Air Force Agency. K237.01 volume 1.

United States Air Force. Air Force Systems Command. Aerospace Medical Division. *History of the Aerospace Medical Division 1 July 1969 – 30 June 1970*. Air Force Historical Research Agency, Maxwell Air Force Agency. K237.01 volume 1.

United States Air Force. Air Force Systems Command. Aerospace Medical Division. *History of the Aerospace Medical Division 1 July 1971 – 30 June 1972*. Air Force Historical Research Agency, Maxwell Air Force Agency. K237.01.

United States Air Force. Air Force Systems Command. Air Force Flight Test Center. *History of the Air Force Flight Test Center 1 July – 31 December 1963*, volume 1. History Office, Edwards Air Force Base.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. "The Air Force Weapons Laboratory (AFWL) 1963-1990." Three-page typescript. ca.1990. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *History of the Air Force Weapons Laboratory 1 May – 31 December 1963*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 2.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *History of the Air Force Weapons Laboratory 1 January – 31 December 1964*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 1.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *History of the Air Force Weapons Laboratory 1 January – 31 December 1965*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 1.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *History of the Air Force Weapons Laboratory 1 January – 31 December 1966*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 1.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *History of the Air Force Weapons Laboratory 1 January – 31 December 1969*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 1.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *History of the Air Force Weapons Laboratory 1 January – 31 December 1970*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 1.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *History of the Air Force Weapons Laboratory 1 January – 31 December 1971*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 1.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *History of the Air Force Weapons Laboratory 1 January – 31 December 1972*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 1.

United States Air Force. Air Force Systems Command. Air Force Weapons Laboratory. *The Silver Anniversary : Air Force Weapons Laboratory 25 Years of Excellence*. Kirtland Air Force Base: Air Force Weapons Laboratory, 1988.

United States Air Force. Air Force Systems Command. Air Proving Ground Center. *History of the Air Proving Ground Center 1 July – 31 December 1961*. Air Force Historical Research Agency, Maxwell Air Force Base. K240.01 volume 4.

United States Air Force. Air Force Systems Command. Armament Development and Test Center. *History of the Armament Development and Test Center 1 July – 31 December 1975*. Air Force Historical Research Agency, Maxwell Air Force Base. K240.01 volume 6.

United States Air Force. Air Force Systems Command. Arnold Engineering Development Center. *A Chronology of the Arnold Engineering Development Center 10 August 1944 – 30 June 1968*. K215.16052.

United States Air Force. Air Force Systems Command. Arnold Engineering Development Center. *Chronology of the Arnold Engineering Development Center 1 July 1970 – 31 December 1977*. K215.16052-1.

United States Air Force. Air Force Systems Command. Rome Air Development Center. *Rome Air Development Center 1951-1971*. ca.1972. History Office, Air Force Research Laboratory, Rome Research Site, New York.

United States Air Force. Air Force Technical Base. *Air Force Technical Base History July – December 1947*. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Air Force. Air Materiel Command. "Background on Runway and Closing of S.E. 59th Street south of Tinker AFB." Typescript. 1954. History Office, Tinker Air Force Base.

United States Air Force. Air Materiel Command. "Electronic Subdivision Facilities Required for the Five Year Program." Typescript, dated through internal references. July 1946. Air Force Historical Research Agency, Maxwell Air Force Base. K215.16-1.

United States Air Force. Air Materiel Command. "German Specialists Assigned to Wright-Patterson AF Base." 15 March 1948 and 15 July 1948, typed lists held in the History Office, Air Force Materiel Command, Wright-Patterson Air Force Base.

United States Air Force. Air Materiel Command. "German Specialists Assigned to Wright-Patterson AF Base." 15 August 1948 and 15 October 1948, typed lists held in the History Office, Aeronautical Systems Center, Air Force Materiel Command, Wright-Patterson Air Force Base.

United States Air Force. Air Materiel Command. [Frederick A. Alling]. *History of the Air Materiel Command 1946*. Air Force Historical Research Agency, Maxwell Air Force Base. 200-6 volume 1.

United States Air Force. Air Materiel Command. [Max Rosenberg]. *History of the Air Materiel Command 1947*. Air Force Historical Research Agency, Maxwell Air Force Base. 200-7 volume 1.

United States Air Force. Air Materiel Command. [Doris A. Baker]. *History of the Air Materiel Command 1948*. Air Force Historical Research Agency, Maxwell Air Force Base. 200-8.

United States Air Force. Air Materiel Command. [Ruth E. Vorce]. *History of the Air Materiel Command 1 January – 30 June 1949*. Air Force Historical Research Agency, Maxwell Air Force Base. 200-9.

United States Air Force. Air Materiel Command. [Frederick A. Alling, Doris A. Baker, Ethel DeHaven, and Max Rosenberg]. *History of the Air Materiel Command 1 July – 31 December 1949*. Air Force Historical Research Agency, Maxwell Air Force Base. 200-9 volume 1.

United States Air Force. Air Materiel Command. [Frederick A. Alling, Ethel M. DeHaven, Helen Brents Joiner, and Clifford A. Morrison]. *History of the Air Materiel Command 1 January – 30 June 1951*. Air Force Historical Research Agency, Maxwell Air Force Base. K200-12 volume 1.

United States Air Force. Air Materiel Command. Air Force Cambridge Research Laboratories. *Cambridge Research Laboratories Historical Data 1 January – 30 June 1950*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-11 volume 11.

United States Air Force. Air Materiel Command. Air Force Cambridge Research Laboratories. *Cambridge Research Laboratories 3160th Electronics Group Historical Data 1 July – 31 December 1950*. Air Force Historical Research Agency, Maxwell Air Force Base. K215.91-12 volume 12, part 1.

United States Air Force. Air Materiel Command. Air Force Cambridge Research Laboratories. *Historical Data Air Force Cambridge Research Laboratories 3160th Electronics Group 1 July – 31 December 1949*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-10 volume 10.

United States Air Force. Air Materiel Command. Ogden Air Materiel Area. *History of the Ogden Air Materiel Area 1 January – 30 June 1955*. History Office, Hill Air Force Base.

United States Air Force. Air Materiel Command. Ogden Air Materiel Area. [Helen Rice, David J. Hefferman, and Harry L. Bonnell]. *History of the Ogden Air Materiel Area 1 July – 31 December 1955*, volume 1. History Office, Hill Air Force Base.

United States Air Force. Air Materiel Command. Ogden Air Materiel Area. [Helen Rice, David J. Hefferman, and Harry L. Bonnell]. *History of the Ogden Air Materiel Area 1 January – 30 June 1956.* Air Force Historical Research Agency, Maxwell Air Force Base. K205.06-28 volume 1

United States Air Force. Air Materiel Command. Ogden Air Materiel Area. *History of the Ogden Air Materiel Area 1 July – 31 December 1956*, volume 1. History Office, Hill Air Force Base.

United States Air Force. Air Materiel Command. Ogden Air Materiel Area. [Helen Rice, David J. Hefferman, and Harry L. Bonnell]. *History of the Ogden Air Materiel Area 1 January – 30 June 1957*, volume 1. History Office, Hill Air Force Base.

United States Air Force. Air Materiel Command. Ogden Air Materiel Area. [Helen Rice and Harry L. Bonnell]. *History of the Ogden Air Materiel Area 1 July – 31 December 1957*, volume 1. History Office, Hill Air Force Base.

United States Air Force. Air Materiel Command. Oklahoma City Air Materiel Area. *History Oklahoma City Air Materiel Area 1 January – 30 June 1951.* Installation XI, Part I. History Office, Tinker Air Force Base.

United States Air Force. Air Materiel Command. Oklahoma City Air Materiel Area. *History Oklahoma City Air Materiel Area 1 July – 31 December 1951*, Installation XII, Part I. History Office, Tinker Air Force Base.

United States Air Force. Air Materiel Command. Oklahoma City Air Materiel Area. *History Oklahoma City Air Materiel Area 1 July – 31 December 1952*, Installation XIV. History Office, Tinker Air Force Base.

United States Air Force. Air Materiel Command. Oklahoma City Air Materiel Area. *History Oklahoma City Air Materiel Area 1 July – 31 December 1955.* History Office, Tinker Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 July – 31 December 1946.* History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 July – 31 December 1948*, Classified [originally] Annex to Installment VI. History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 January – 30 June 1952.* History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 July – 31 December 1952.* History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 January – 30 June 1953*. History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 July – 31 December 1953*. History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 January – 30 June 1954*. History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 July – 31 December 1954*. History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 January – 30 June 1955*. History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 July – 31 December 1955*. History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of San Antonio Air Materiel Area 1 January – 30 June 1957*. History Office, Kelly Air Force Base.

United States Air Force. Air Materiel Command. San Antonio Air Materiel Area. *History of the San Antonio Air Materiel Area 1 July – 31 December 1957*. History Office. Kelly Air Force Base.

United States Air Force. Air Materiel Command. T-3 Engineering. Electronic Subdivision. "Facilities Required for the Five Year Program." Dated through verifiable internal references to March-July 1946. Air Force Historical Research Agency, Maxwell Air Force Base. K215.16-1.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. *History of Warner Robins AMA 1 January – 30 June 1953*, including supplement. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. *History of Warner Robins AMA 1 January – 30 June 1954*. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. *History of Warner Robins AMA 1 January – 30 June 1955*. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. [Robert W. Barnwell and Lewis J. Carry]. *History of the Warner Robins Air Materiel Area 1 July – 31 December 1955*. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. [Robert W. Barnwell and Lewis J. Carey]. *History of Warner Robins Air Materiel Area 1 January – 30 June 1956*. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. [Robert W. Barnwell and Patillo A. Finlayson]. *History of Warner Robins Air Materiel Area 1 July – 31 December 1956*. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. [Robert W. Barnwell and P. A. Finlayson]. *History of Warner Robins Air Materiel Area 1 July – 31 December 1957*. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. [Robert W. Barnwell and P.A. Finlayson]. *History of Warner Robins Air Materiel Area 1 January – 30 June 1958*. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Warner Robins Air Materiel Area. *History of Warner Robins Air Materiel Area 1 July – 31 December 1958*. History Office, Robins Air Force Base.

United States Air Force. Air Materiel Command. Watson Laboratories. "Minutes Data Transmission Meeting with Tactical Air Command. 16 and 17 September 1948." Air Force Historical Research Agency, Maxwell Air Force Base. 215.9-151.

United States Air Force. Air Materiel Command. Watson Laboratories. 3151st Electronics Group. *Review of the Watson Laboratories' Development Program of Electronic Equipment and Systems for Air Defense (Prepared for 6 – 7 July 1950 Conference at the Griffiss Air Force Base)*, 3 July 1950. Air Force Historical Research Agency, Maxwell Air Force Base. 215.9-101.

United States Air Force. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Historical Data Cambridge Field Station 3160th Electronics Station 1 January – 30 June 1949*. Air Force Historical Research Agency, Maxwell Air Force Base. 215-91-9 volume 9.

United States Air Force. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Unit History of 4135th Air Force Base Unit Cambridge Field Station 1 January – 30 June 1948*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-7.

United States Air Force. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Unit History Cambridge Field Station 3160th Electronics Station 1 July – 31 December 1948*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-8 volume 8, parts 1-2.

United States Air Force. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Unit History of Watson Laboratories Cambridge Field Station 1 January – 31 March 1947*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-3.

United States Air Force. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Unit History of Watson Laboratories Cambridge Field Station 1 April – 30 June 1947*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-4.

United States Air Force. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Unit History of Watson Laboratories Cambridge Field Station 1 July – 30 September 1947*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-5.

United States Air Force. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Unit History of Watson Laboratories Cambridge Field Station 1 October – 31 December 1947*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-6.

United States Air Force. Air Proving Ground Command. *Air Proving Ground Historical Data 2 September 1945 – 30 June 1949*. Air Force Historical Research Agency, Maxwell Air Force Base. 240.01 volumes 1-4.

United States Air Force. Air Proving Ground Command. Air Force Operational Test Center. *History of the Air Force Operational Test Center 1 July – 31 December 1954*. Air Force Historical Research Agency, Maxwell Air Force Base. K230.3024 volume 1.

United States Air Force. Air Proving Ground Command. 3200th Proof Test Group. *3200th Proof Test Group History 1 July – 31 December 1950*. Air Force Historical Research Agency, Maxwell Air Force Base. K-GP-TEST-3200-HI (DRONE) volume 1.

United States Air Force. Air Research and Development Command. [Ernest G. Schweibert]. *History of the Air Research and Development Command 1 July 1951 – 31 December 1952*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.01 volumes 1-2.

United States Air Force. Air Research and Development Command. Air Force Cambridge Research Laboratories. *History of USAF Cambridge Research Laboratories 1 January – 1 April 1951*. Air Force Historical Research Agency, Maxwell Air Force Base. K215.91-13 volume 13, part 1.

United States Air Force. Air Research and Development Command. Air Force Cambridge Research Center. *History of the Air Force Cambridge Research Center 1 April – 30 June 1951*. Air Force Historical Research Agency, Maxwell Air Force Base. K215.91-14 volume 14, part 1.

United States Air Force. Air Research and Development Command. Air Force Cambridge Research Center. *History of the Air Force Cambridge Research Center 1 July – 31 December 1951*. Air Force Historical Research Agency, Maxwell Air Force Base. K215.91-15 volume 15, part 1.

United States Air Force. Air Research and Development Command. Air Force Cambridge Research Center. *History of the Air Force Cambridge Research Center 1 January – 30 June 1952*. Air Force Historical Research Agency, Maxwell Air Force Base. K215.91-16 volume 16, part 1.

United States Air Force. Air Research and Development Command. Air Force Cambridge Research Center. *History of the Air Force Cambridge Research Center 1 July – 31 December 1952*. Air Force Historical Research Agency, Maxwell Air Force Base. K215.91-16 volume 17, part 1.

United States Air Force. Air Research and Development Command. Air Force Cambridge Research Center. *History of the Air Force Cambridge Research Center 1 January – 30 June 1953*. Air Force Historical Research Agency, Maxwell Air Force Base. K215.91-17 volume 18, part 1.

United States Air Force. Air Research and Development Command. Air Force Flight Test Center. *History of Air Force Flight Test Center 2 April – 30 June 1951*. History Office, Edwards Air Force Base.

United States Air Force. Air Research and Development Command. Air Force Flight Test Center. *History of Air Force Flight Test Center 1 July – 31 December 1951*. History Office, Edwards Air Force Base.

United States Air Force. Air Research and Development Command. Air Force Flight Test Center. *History of the Air Force Flight Test Center 1 July – 31 December 1952*. History Office, Edwards Air Force Base.

United States Air Force. Air Research and Development Command. Air Force Flight Test Center. *History of the Air Force Flight Test Center 1 January – 30 June 1955*. History Office, Edwards Air Force Base.

United States Air Force. Air Research and Development Command. Air Force Special Weapons Center. "Air Force Special Weapons Center: A Brief History." Four-page typescript. 1 April 1952. Air Force Historical Research Agency, Maxwell Air Force Base. K242.01.

United States Air Force. Air Research and Development Command. Air Force Special Weapons Center. *History of the Air Force Special Weapons Center for 1953*. Air Force Historical Research Agency, Maxwell Air Force Base. K242.01 volume 1.

United States Air Force. Air Research and Development Command. Air Force Special Weapons Center. *History of the Air Force Special Weapons Center 1 January – 31 December 1954*. Air Force Historical Research Agency, Maxwell Air Force Base. K242.01 volume 1.

United States Air Force. Air Research and Development Command. Air Force Special Weapons Center. *History of the Air Force Special Weapons Center 1 January – 30 June 1955*. Air Force Historical Research Agency, Maxwell Air Force Base. K242.01 volume 1.

United States Air Force. Air Research and Development Command. Air Force Special Weapons Center. *History of the Air Force Special Weapons Center 1 January – 30 June* 1956. Air Force Historical Research Agency, Maxwell Air Force Base. K242.01 volume 1.

United States Air Force. Air Research and Development Command. Air Force Special Weapons Center. *History of the Air Force Special Weapons Center 1 July – 31 December 1956*. Air Force Historical Research Agency, Maxwell Air Force Base. K242.01 volume 1.

United States Air Force. Air Research and Development Command. Air Force Special Weapons Center. *History of the Air Force Weapons Laboratory 1 January – 31 December 1964*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.0145 volume 1.

United States Air Force. Air Research and Development Command. Air Force Special Weapons Center. *Semiannual History of the Air Force Special Weapons Center 1 April – 31 December 1952*. Air Force Historical Research Agency, Maxwell Air Force Base. K242.01 volume 1.

United States Air Force. Air Research and Development Command. Arnold Engineering Development Center. *AEDC WADC Facilities Study Group*, 1952. K215.16164-1 volume 2.

United States Air Force. Air Research and Development Command. Arnold Engineering Development Center. *History of Arnold Engineering Development Center 1944-1951.* Air Force Historical Research Agency, Maxwell Air Force Base. K215.16.

United States Air Force. Air Research and Development Command. Arnold Engineering Development Center. *History of the Arnold Engineering Development Center 1 January – 30 June 1951.* Air Force Historical Research Agency, Maxwell Air Force Base. K215.16 volumes 1-2.

United States Air Force. Air Research and Development Command. Arnold Engineering Development Center. *History of the Arnold Engineering Development Center 1 January – 30 June 1952.* Air Force Historical Research Agency, Maxwell Air Force Base. K215.16 volumes 1-3.

United States Air Force. Air Research and Development Command. Arnold Engineering Development Center. *History of the Arnold Engineering Development Center 1 July – 31 December 1954.* Air Force Historical Research Agency, Maxwell Air Force Base. K215.16.

United States Air Force. Air Research and Development Command. Arnold Engineering Development Center. *History of the Arnold Engineering Development Center 1 July – 31 December 1955.* Air Force Historical Research Agency, Maxwell Air Force Base. K215.16 volume 1.

United States Air Force. Air Research and Development Command. Arnold Engineering Development Center. *Policy on the Use of ARDC Research & Development Test Facilities with Specific Reference to the Arnold Engineering Development Center*, 1949-1953. Air Force Historical Research Agency, Maxwell Air Force Base. K215.16164-1 volume 1.

United States Air Force. Air Research and Development Command. Rome Air Development Center. *Historical Data Rome Air Development Center 3 April – 30 June 1951.* History Office, Air Force Research Laboratory, Rome Research Site, New York.

United States Air Force. Air Research and Development Command. Rome Air Development Center. *Historical Data Rome Air Development Center 1 July – 31 December 1951*, volume 2. History Office, Air Force Research Laboratory, Rome Research Site, New York.

United States Air Force. Air Research and Development Command. Rome Air Development Center. *Historical Data Rome Air Development Center 1 January – 30 June 1952*, volume 2. History Office, Air Force Research Laboratory, Rome Research Site, New York.

United States Air Force. Air Research and Development Command. Rome Air Development Center. *Historical Data Rome Air Development Center 1 July – 31 December 1952.* Air Force Historical Research Agency, Maxwell Air Force Base. K243.021 volumes 1-2.

United States Air Force. Air Research and Development Command. Rome Air Development Center. *Historical Data Rome Air Development Center 1 January – 30 June 1953*, supplement. History Office, Air Force Research Laboratory, Rome Research Site, New York.

United States Air Force. Air Research and Development Command. Rome Air Development Center. *Historical Data Rome Air Development Center 1 July – 31 December 1953*, supplement. History Office, Air Force Research Laboratory, Rome Research Site, New York.

United States Air Force. Air Research and Development Command. Wright Air Development Center. [Margaret A. Kennedy and Robert L. Perry]. *The Establishment of Wright Air Development Center March – November 1951*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.01 volume 1.

United States Air Force. Air Research and Development Command. Wright Air Development Center. *History of Wright Air Development Center 1 January – 30 June 1952*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.01 volume 2.

United States Air Force. Air Research and Development Command. Wright Air Development Center. *History of Wright Air Development Center 1 July – 31 December 1952*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.01 volume 2.

United States Air Force. Air Research and Development Command. Wright Air Development Center. [Margaret A. Kennedy, Robert L. Perry, and Max Rosenberg]. "New Facilities for WADC." *History of Wright Air Development Center 1 July – 31 December 1951*. Air Force Historical Research Agency, Maxwell Air Force Base. K243.01 volume 2.

United States Air Force. Air Research and Development Command. Wright Air Development Center. "Organizations / WADC," 1953-1956, Range 4, Area C, Row 6, History Office, Aeronautical Systems Center, Air Force Materiel Command, Wright-Patterson Air Force Base.

United States Air Force. Air Research and Development Command. Wright Air Development Center. *Semi-Annual History of the Aircraft Laboratory 1 January – 1 July 1955*, in *Historical Reports January – June 1955*. History Office, Aeronautical Systems Center, Air Force Materiel Command, Wright-Patterson Air Force Base.

United States Air Force. Air Research and Development Command. Wright Air Development Center. *Semiannual History Directorate of Research 30 June 1956 – 1 January 1957*. History Office, Aeronautical Systems Center, Air Force Materiel Command, Wright-Patterson Air Force Base.

United States Air Force. Air Research and Development Command. Wright Air Development Center. *Users' Manual United States Air Force SMART Track*, ca.1955. History Office, Aeronautical Systems Center, Air Force Materiel Command, Wright-Patterson Air Force Base.

United States Air Force. Air University. *Annual History 1948-1949 School of Aviation Medicine*. Air Force Historical Research Agency, Maxwell Air Force Base. 239.07 volume 8.

United States Air Force. Air University. *A Proposed United States Air Force Aeromedical Center August 1946 – August 1949*. Air Force Historical Research Agency, Maxwell Air Force Base. K141.2821-4 August 1946 – August 1949.

United States Air Force. Air University. *USAF School of Aviation Medicine Correspondence, Memoranda, Studies, and Plans January 1950 – December 1953*. Air Force Historical Research Agency, Maxwell Air Force Base. K141.2821-4.

United States Air Force. Edwards Air Force Base. "Fighter Sqdn Detachment Operational Here," *Desert Wings*. 2 August 1963. History Office, Edwards Air Force Base.

United States Air Force. Edwards Air Force Base. *History of Edwards Air Force Base Muroc, California 1 July – 31 December 1950*. History Office, Edwards Air Force Base.

United States Air Force. Edwards Air Force Base. Office of Real Property. Area A Real Property Cards, Edwards Air Force Base.

United States Air Force. Hanscom Air Force Base. *Basic Information Folder Hanscom Airport Bedford, Mass.* April 1951. History Office, Hanscom Air Force Base.

United States Air Force. Headquarters. "Architect-Engineer Services for Air Force Work Furnished by Pereira and Luckman." Memorandum for the Under Secretary of the Air Force from the Directorate of Construction, Assistant Chief of Staff, Installations. 20 December 1954. Record Group 341, Entry 494, Box 496, File "A&E Contracts Nov-Dec 1954." National Archives II, Maryland.

United States Air Force. Headquarters. *History of the Assistant Chief of Staff, Installations 1 July – 31 December 1954*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 6, part 1.

United States Air Force. Headquarters. *History of the Assistant Chief of Staff, Installations 1 July – 31 December 1955*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 6.

United States Air Force. Headquarters. *History of the Assistant Chief of Staff, Installations 1 January – 30 June 1956*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 7.

United States Air Force. Headquarters. *History of the Assistant Chief of Staff, Installations 1 July – 31 December 1956*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 8.

United States Air Force. Headquarters. *History of the Assistant Chief of Staff, Installations 1 January – 30 June 1957*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 8.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1959*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 9.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1959*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 7.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1960*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 8.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1960*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 8.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1961*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 5.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1961*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 5.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1962*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 5.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1962*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1963*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 2.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1964*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 5.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1964*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 5.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1966*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1966*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1966*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1967*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1967*. Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1968.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1968.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1969.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1969.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1970.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1970.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1971.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3, part 1.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1971.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 January – 30 June 1972.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 3, part 1.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1973.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 2.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1974.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 2.

United States Air Force. Headquarters. *History of the Directorate of Civil Engineering 1 July – 31 December 1975.* Air Force Historical Research Agency, Maxwell Air Force Base. K145.01 volume 1.

United States Air Force. Headquarters. *History of the Directorate of Installations 1 January – 30 June 1957*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 8.

United States Air Force. Headquarters. *History of the Directorate of Installations 1 July – 31 December 1957*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 6.

United States Air Force. Headquarters. *History of the Directorate of Installations 1 January – 30 June 1958*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 8.

United States Air Force. Headquarters. *History of the Directorate of Installations 1 July – 31 December 1958*. Air Force Historical Research Agency, Maxwell Air Force Base. K143.01 volume 7.

United States Air Force. Headquarters. Research and Development Directorate. *Review of the Site Survey for the AEDC*, 30 December 1948. History Office, Arnold Engineering Development Center.

United States Air Force. Kelly Air Force Base. "B-52." Vertical file. History Office, Kelly Air Force Base. Location of the files after base realignment in July 2001 is anticipated as Lackland Air Force Base.

United States Air Force. Kelly Air Force Base. Various Buildings and Aircraft. Vertical files. History Office, Kelly Air Force Base. Location of the files after base realignment in July 2001 is anticipated as Lackland Air Force Base.

United States Air Force. Muroc Army Air Field. *History of Muroc Army Air Field 1 July to 31 December 1947*. History Office, Edwards Air Force Base.

United States Air Force. Secretary of the Air Force. Office of Public Affairs. "LGM-30 Minuteman," *United States Air Force Fact Sheet*. May 1987.

United States Air Force. Secretary of the Air Force. Office of Public Affairs. *Peacekeeper Fact Sheet*. July 1990.

United States Air Force. Special Weapons Command. *History Special Weapons Command 1 December 1949 – 30 June 1950*. Air Force Historical Research Agency, Maxwell Air Force Base. 242.01.

United States Air Force. Strategic Air Command. *Historical Data 3906th Air Base Group 1 March – 31 May 1953*. Air Force Historical Research Agency, Maxwell Air Force Base. K-GP-AB-3906-HI.

United States Air Force. Strategic Air Command. *History of 3906th Air Base Group 1 January – 30 June 1957*. Air Force Historical Research Agency, Maxwell Air Force Base. K-GP-AB-3906-HI.

United States Air Force. Strategic Air Command. *History of 7280th Air Depot Wing 1 May – 30 June 1953*. Air Force Historical Research Agency, Maxwell Air Force Base. K-WG-DEP-7280-HI volume 1.

United States Air Force. Strategic Air Command. *History of 7280th Air Depot Wing 1 July – 30 September 1953*. Air Force Historical Research Agency, Maxwell Air Force Base. K-WG-DEP-7280-HI volume 2.

United States Air Force. Strategic Air Command. *The SAC Bombardment Training Program 1946-1959*, Strategic Air Command Historical Study No. 80. Air Force Historical Research Agency, Maxwell Air Force Base. K416.01-80 1946-1959.

United States Air Force. Tactical Air Command. *History of 552nd Airborne Warning & Control Wing 1 October – 31 December 1976*. Air Force Historical Research Agency, Maxwell Air Force Base. K-WG-552-HI volume 1.

United States Air Force. Tactical Air Command. *History of 552nd Airborne Warning & Control Wing 1 January – 30 March 1977*. Air Force Historical Research Agency, Maxwell Air Force Base. K-WG-552-HI volume 1.

United States Air Force. Tactical Air Command. *History of 552nd Airborne Warning & Control Wing 1 January – 31 December 1978* Air Force Historical Research Agency, Maxwell Air Force Base. K-WG-552-HI volume 1.

United States Air Force. Tactical Air Command. 560th Civil Engineering Squadron (Heavy Repair). *History of the 560th Civil Engineering Squadron (Heavy Repair) (TAC) 1 July – 31 December 1967*. Air Force Historical Research Agency, Maxwell Air Force Base. K-SQ-INST-560-HI.

United States Air Force. Tactical Air Command. 560th Civil Engineering Squadron (Heavy Repair). *History of the 560th Civil Engineering Squadron (Heavy Repair) (TAC) 1 January – 30 June 1968*. Air Force Historical Research Agency, Maxwell Air Force Base. K-SQ-INST-560-HI volume 3.

United States Air Force. United States Air Force Medical Service. *A Semi-Annual History of the Office of the Surgeon General 1 July – 31 December 1969*. Air Force Historical Research Agency, Maxwell Air Force Base. K141.28.

United States Air Force. Wright-Patterson Air Force Base. "Building 1421," "Building 1420," and "Building 1418 & 1419." Files, History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Air Force. Wright-Patterson Air Force Base. *History of Wright-Patterson Air Force Base 1 January – 30 June 1951*. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Air Force. Wright-Patterson Air Force Base. *History of Wright-Patterson Air Force Base July – December 1954*. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Air Force. Wright-Patterson Air Force Base. *History of Wright-Patterson Air Force Base January – December 1955*. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Air Force. Wright-Patterson Air Force Base. *History of Wright-Patterson Air Force Base January – June 1956*. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Air Force. Wright-Patterson Air Force Base. *History of Wright-Patterson Air Force Base 1 January – 30 June 1958*. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Air Force. Wright-Patterson Air Force Base. "Minutes of the Wright-Patterson Air Force Base Planning Board." 24 May 1948, 23 August 1948, 22 October 1948, 18, 19 May 1949, 6 April 1954, 19 January 1956 and 16 August 1956. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Air Force. Wright-Patterson Air Force Base. *A Tour of Wright-Patterson Air Force Base*. 27 October 1955. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Army. Air Corps Board. Maxwell Field. *Report on Plan for Underground Aviation Facilities*, 9 January 1936. Microfiche file. History Office, Air Force Materiel Command, Wright-Patterson Air Force Base.

United States Army Air Forces. Air Materiel Command. Army Air Forces Technical Base. *Preliminary Master Plan Report*. Dayton: AAF Technical Base, 1947. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

United States Army Air Forces. Air Materiel Command. Watson Laboratories. *Electronics Subdivision Manufacturer's Conference 26-27-28 June 1946 Watson Laboratories, Red Bank, N.J.* Air Force Historical Research Agency, Maxwell Air Force Base. 215.9-152.

United States Army Air Forces. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Unit History of Watson Laboratories Cambridge Field Station 3 September 1945 – 30 June 1946*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-1.

United States Army Air Forces. Air Materiel Command. Watson Laboratories. Cambridge Field Station. *Unit History of Watson Laboratories Cambridge Field Station 1 July – 31 December 1946*. Air Force Historical Research Agency, Maxwell Air Force Base. 215.91-2.

United States Army Air Forces. Air Technical Service Command. [Irving R. Friend]. *History of the Air Technical Service Command 1945*. Air Force Historical Research Agency, Maxwell Air Force Base. 200-6 volume 1.

United States Army Air Forces. Air Technical Service Command. [T.W. Mitchell, Imogene B. Walker, and Duane D. Smith.] *History of the Army Air Forces Air Service Command 1921-1944*, volume 1. Air Force Historical Research Agency, Maxwell Air Force Base. 200-4 volume 1 1921-1944.

United States Army Air Forces. Air Technical Service Command. Engineering Division. *Proposed Air Engineering Development Center*, 10 December 1945. History Office, Arnold Engineering Development Center.

Walker, Lois E. and Shelby E. Wickam. *From Huffman Prairie to the Moon: The History of Wright-Patterson Air Force Base*. Wright-Patterson Air Force Base: History Office, 2750th Air Base Wing, 1986.

Western Electric Company. *DEW East Completion Report*, 30 March 1962. Air Force Historical Research Agency, Maxwell Air Force Base. K167.861-13.

Wilman, J. Catherene. *Space Division: A Chronology, 1980-1984*. Los Angeles Air Force Station: History Office, Space Division, ca.1984.

Young, James O., Raymond L. Puffer and Frederick A. Johnson. "The Air Force Flight Test Center." Typescript of a draft essay composed for the History Office, Headquarters United States Air Force. 30 January 1996.

Drawings, Master Plans, and Maps

"2234th USAFR Training Center Hanscom Airport Bedford Telephone Cable Chart." 10 May 1949. Civil Engineering Vault. Hanscom Air Force Base.

"Advanced Airborne Demonstrator Complex. Site and Location Plans." 1 July 1982. Civil Engineering Vault. Kirtland Air Force Base.

Air Force Cambridge Research Center. "Plan Existing Facilities MEW Hill and Misc. Details." 1953. Civil Engineering Vault. Hanscom Air Force Base.

Air Force Cambridge Research Center. "Rawinsonde Bldg." Drawing 35-50-01. 9 June 1953. Civil Engineering Vault. Hanscom Air Force Base.

Air Force Cambridge Research Center. "Transmitter & Receiver Bld'gs." Drawing 38-12-02. 21 February 1955. Civil Engineering Vault. Hanscom Air Force Base.

Air Force Materiel Command. "Comprehensive Plan Los Angeles Annex #3." 15 April 1999. Civil Engineering Vault. Los Angeles Air Force Base.

Air Force Systems Command. "Comprehensive Plan Basic Layout Plan Edwards Air Force Base." 1 February 1963. Civil Engineering Vault. Edwards Air Force Base.

Air Force Systems Command. "Location of Headquarters Office of the Deputy Commander (AFSC) for Aeropsace Systems, Los Angeles 45, California." Undated. Civil Engineering Vault. Edwards Air Force Base.

Air Force Systems Command. "Master Plan Basic Mission Development Plan Brooks Air Force Base." 1 January 1962. Civil Engineering Vault. Brooks Air Force Base.

Air Force Systems Command. "Natural Obstructions RCS: SYS-DEE(A)7201 Hanscom Field." 1 January 1960, revised to 1 February 1973. Civil Engineering Vault. Hanscom Air Force Base.

Air Installations Office. Kirtland Air Force Base. "F-86D Flight Simulator Technical Training Building." December 1953. Civil Engineering Vault. Kirtland Air Force Base.

Air Installations Office. Kirtland Air Force Base. "Pavement Evaluation." December 1948. Listed revisions of 16 September 1948 and 5 January 1950. Civil Engineering Vault. Kirtland Air Force Base.

Air Installations Office. Robins Air Force Base. "Modify Building 116 for Packing & Crating Shop." 4 May 1956. Microfiche. Civil Engineering Vault. Robins Air Force Base.

Air Installations Office. Robins Air Force Base. "Plan for Enclosing North End of Building No. 105 and Replacing Gypsum Siding on buildings Nos. 105 and 116 with Corregated [*sic*] Metal." 8 July 1949. Microfiche. Civil Engineering Vault. Robins Air Force Base.

Air Installations Office. Wright-Patterson Air Force Base. "PT. of Area 'C' W-P A.F.B. Building Plan." Baseline date of 2 February 1945, updated to September 1949. In File "56th Fighter-Interceptor Squadron & 97th FIS," Box "WPAFB Former Units," History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

Air Installations Office. Wright-Patterson Air Force Base. "U.S. Army Air Forces Wright Field Areas A and B. Areas Occupied by 97th Fighter Squadron." Baseline date of 15 January 1945, updated to March 1951. History Office, 88th Air Base Wing, Wright-Patterson Air Force Base.

Air Materiel Command. "Basic Layout Plan Griffiss Air Force Base." 4 February 1957. Storage Area, adjacent to the transitional environmental planning offices. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

Air Materiel Command. "Master Plan Airfield Pavement Plan Griffiss Air Force Base." 4 February 1957. Storage Area, adjacent to the transitional environmental planning offices. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

Air Materiel Command. "Master Plan Forestport Site Griffiss Air Force Base." 4 February 1957. Storage Area, adjacent to the transitional environmental planning offices. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

Air Materiel Command. "Master Plan Off-Base Facilities Griffiss Air Force Base." 4 February 1957. Storage Area, adjacent to the transitional environmental planning offices. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

Air Materiel Command. "Master Plan Verona Site Griffiss Air Force Base." 4 February 1957. Storage Area, adjacent to the transitional environmental planning offices. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

Air Materiel Command, with Western Electric Co., Inc., and, Burns & Roe, Inc. "SAGE ADES Project Ops-C Building and Ops-D Building." Drawing number and original date unclear. Civil Engineering Vault. Minot Air Force Base.

Air Research and Development Command. "Air Defense Laboratory." Drawing 35-06-06. 9 March 1954. Civil Engineering Vault. Hanscom Air Force Base.

Air Research and Development Command. "Airfield Pavement L. G. Hanscom Field." September 1956. Civil Engineering Vault. Hanscom Air Force Base.

Allen & Kelley. "30,000 HP Propeller Test Stand." 2 June 1951. Civil Engineering Vault. Wright-Patterson Air Force Base.

Ammann & Whitney. "Griffiss Air Force Base Special A.M.C. Warehouse Building No. 3 – Frame Repairs." 1 May 1957. Civil Engineering Vault. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

Ammann & Whitney and L.P. Kooken. "Hill Air Force Base Special A.M.C. Warehouse, 400' by 1400'." Drawing 33-02-02. 20 May 1955. Civil Engineering Vault. Hill Air Force Base.

Ammann & Whitney. "Special AMC Warehouses Robins Air Force Base Roof Repairs." 24 January 1957. Microfiche. Civil Engineering Vault. Robins Air Force Base.

Anderson-Nichols & Company. "Electronic Radio-Chemistry Laboratory." Drawing AW 35-06-24. August 1956. Civil Engineering Vault. Hanscom Air Force Base.

Anderson-Nichols & Co., Inc. "Radiation Physics Laboratory." Drawing AW 35-06-55. February 1962. Civil Engineering Vault. Hanscom Air Force Base.

"Area 'A' Housing Improvements Architectural Plans & Elevations." February 1972. Civil Engineering Vault. Edwards Air Force Base.

"Area 'A' Housing Improvements Plot & Drainage Plans (Sheet 1)." February 1972. Civil Engineering Vault. Edwards Air Force Base.

ARMCO. "Shelter B-47 Nose Dock." 4 January 1955. Adaptation of Armco drawing 54-85E. Air Force Plant 6. Marietta, Georgia.

Army Air Forces Technical Base, Wright Field. "Three Fungi Labs, Temperature & Humidity Materials Laboratory Bldg. 16." Job #27-5188. 3 July 1946. Civil Engineering Vault. Wright-Patterson Air Force Base.

The Austin Company. "Modification Center No. 17." 15 May 1943. Civil Engineering Vault. Tinker Air Force Base.

"Ballistic Missile Process Support Facility." 21 July 1976. Civil Engineering Vault. Hill Air Force Base.

"Base Facilities Area Development Present Mission & VVHB Runway System." 30 March 1947. Storage Area, adjacent to the transitional environmental planning offices. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

Black & Veatch. "Ammo Storage, Multicubicle Magazine Base." Drawing AW 33-13-19. July 1958. Civil Engineering Vault. Wright-Patterson Air Force Base.

Black & Veatch. "Ammunition Storage Area Ammo Storage, Multicubicle." Drawing AW 33-13-19. July 1958. Civil Engineering Vault. Wright-Patterson Air Force Base.

Black & Veatch. "Ammunition Storage Area Ammo Surveillance and Inspection." Drawing AW 35-69-05. July 1958. Civil Engineering Vault. Wright-Patterson Air Force Base.

Black & Veatch. "Igloo, Storage Steel Arch – Mounded (SAC Type)." Drawing AW 33-15-64. 10 May 1963. Civil Engineering Vault. Hill Air Force Base.

Black & Veatch. "Minuteman Reentry Systems Depot." Drawing 35-32-32. 11 October 1968. Civil Engineering Vault. Hill Air Force Base.

Black & Veatch. "Newfoundland Mountain Air Force Range Multi-Cubicle Test Magazine ADC Type." Drawing AW 33-13-01. 2 May 1960. Civil Engineering Vault. Hill Air Force Base.

Black & Veatch. "Newfoundland Mountain Air Force Range Multi-Cubicle Test Magazine SAC Type." Drawing AW 33-13-01. 2 May 1960. Civil Engineering Vault. Hill Air Force Base.

Black & Veatch. "Storage Units for Haz Exp Assemblies & Components Propulsion System Rocket Facility." Drawing 35-32-32. 11 October 1968. Civil Engineering Vault. Hill Air Force Base.

Black & Veatch, consulting engineers, with W.C. Kruger and Associates. "Troop and Administration Facilities Sandia Base. Post Administration Building." 29 January 1947. Civil Engineering Vault. Kirtland Air Force Base.

William Burk Jr. "Instrumentation Laboratory." March 1952. Civil Engineering Vault. Kirtland Air Force Base.

Burns & McDonnell. "Maintenance Dock, Large AC (CONAC)" Drawing 39-05-16. 20 April 1964. Civil Engineering Vault. Hanscom Air Force Base.

Burns & McDonnell. "WS133A Engine Surveillance Facilities." 7 October 1960. Civil Engineering Vault. Hill Air Force Base.

Butler Manufacturing Company "Office Buildings for the RAND Corporation Lawrence G. Hanscom AFB." 20 August 1956. Civil Engineering Vault. Hanscom Air Force Base.

Kenneth S. Clark. "Readiness Crew." July 1957. Civil Engineering Vault. Kirtland Air Force Base.

Commonwealth of Massachusetts State Airport Management Board. "High & Medium Intensity Runway Lighting Master Plan." 1 March 1950. Civil Engineering Vault. Hanscom Air Force Base.

Congdon, Gurney & Towle, Inc. "Atmospheric Thermal Radiation Field Test Facilities." Drawing 35-06-21. May 1956. Civil Engineering Vault. Hanscom Air Force Base.

Congdon, Gurney & Towle, Inc. "Electro Magnetic Bldg." Drawing 35-06-26. August 1957. Civil Engineering Vault. Hanscom Air Force Base.

Congdon, Gurney & Towle, Inc. "Electronics Laboratory Airborne Facility." Drawing AW 35-06-35. 24 December 1957. Civil Engineering Vault. Hanscom Air Force Base.

Congdon, Gurney & Towle. "Heavy Radar Assembly Bldg." Drawing 35-61-01. Undated. Civil Engineering Vault. Hanscom Air Force Base.

Congdon, Gurney & Towle Inc. "Propagation Studies Bldg." Drawing 32-11-01. ca.1955, first revision date of 7 September 1955. Civil Engineering Vault. Hanscom Air Force Base.

"Construct a Collimator Pit in Building NR 205." 26 June 1956. Civil Engineering Vault. Tinker Air Force Base.

Barlett Cooke and W.E. Simpson Company. "Airmen's Barracks Connecting Utilities. Kelly Air Force Base." May 1951. Civil Engineering Vault. Kelly Air Force Base. Location after realignment is the Civil Engineering Vault, Lackland Air Force Base.

Cram & Ferguson. "Air Force Bedford Research Center Air Defense Laboratory Building C." Drawing 35-06-02. 28 December 1951. Revised 24 October 1952 by Alexander D. Crosett & Associates for Griffiss Air Force Base Laboratory. Storage Area, adjacent to the transitional environmental planning offices. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

Leo A. Daly. "Aircraft Paint Facility." Drawing AW 35-28-06. Stamped date of 30 April 1968. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Leo A. Daly. "Disassembly-Assembly Building." Drawing AW 35-69-04, [Building 940]. 12 July 1962. Civil Engineering Vault. Hill Air Force Base.

Leo A. Daly. "Missile Assembly Building. Boeing Airplane Company. Air Force Plant No. 77." 15 July 1960. Civil Engineering Vault. Hill Air Force Base.

Leo A. Daly. "Missile Maintenance Facility." Drawing AW 35-69-03, [Building 935]. 12 July 1962. Civil Engineering Vault. Hill Air Force Base.

Leo A. Daly. "Readiness Crew Building 70 Men." Drawing AW 30-11-12. 10 April 1958 (adapted for Wright-Patterson Air Force Base 15 December 1958). Civil Engineering Vault. Wright-Patterson Air Force Base.

A. L. Delaney & Associates. "Linear Accelerator Laboratory." Drawing AW 35-06-53. November 1961. Civil Engineering Vault. Hanscom Air Force Base.

Directorate of Installations. Headquarters, United States Air Force. "Brooks Air Force Base," "Edwards Air Force Base," "Eglin Air Force Base," "Griffiss Air Force Base," "Laurence G. Hanscom Field," "Hill Air Force Base," "Kelly Air Force Base," "Kirtland Air Force Base," "McClellan Air Force Base," "Robins Air Force Base," "Tinker Air Force Base," and "Wright-Patterson Air Force Base" (two sheets). Master Plans. 1 October 1957. Author's personal collection. Known other complete sets of Air Force-wide master plans of 1 October 1957 held in the Civil Engineering Vaults at Cannon Air Force Base in New Mexico and Hanscom Air Force Base in Massachusetts, with anticipated acquisition by the Air Force Historical Research Agency, Maxwell Air Force Base in 2003.

Edgerton, Germeshausen & Grier, "EMP Test Simulator Lab," 1964. Civil Engineering Vault. Kirtland Air Force Base.

Edgerton, Germeshausen & Grier. "Vertically Polarized Dipole II Facility." 21 May 1976. Civil Engineering Vault. Kirtland Air Force Base.

Edwards & Rosser, Inc. "Additions to and Alterations of Aircraft Protective Coating Facility." July-September 1974. Microfiche. Civil Engineering Vault. Robins Air Force Base.

"Electronic Test Facility Radar Depot." Drawing 35-03-06. 19 April 1967. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Electronics Systems Division. "Seismic, Gravity Pier, Facility." Drawing 35-06-11. 28 January 1967. Civil Engineering Vault. Hanscom Air Force Base.

"Extension to Flight Line Security Fence." 7 March 1957. Civil Engineering Vault. Edwards Air Force Base.

Franceschi & Dreyfuss, and, Rickey & Brooks, Sacramento. "Special Projects Laboratory Addition." 15 May 1959. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Franceschi & Dreyfuss, and, Rickey & Brooks, Sacramento. "Special Projects Laboratory Addition FY1957." Drawing 35-06002. 14 January 1957. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Ganteaume & McMullen. "GAM 72 Facilities Engine Test Cell." Drawing AW 60-08-03. January 1959. Civil Engineering Vault. Wright-Patterson Air Force Base.

Ganteaume & McMullen. "GAM 77 Facilities Missile Run-Up Shop." Drawing AW 60-08-04. March 1959. Civil Engineering Vault. Wright-Patterson Air Force Base.

Ganteaume & McMullen. "GAM-77 / GAM-72 Service Shop." Drawing AW 35-01-02. March 1959. Civil Engineering Vault. Wright-Patterson Air Force Base.

Giffels & Rossetti. "Corrosion Control Facility, Covered." Drawing AW 39-10-83. 16 November 1960. Adapted for Robins Air Force Base by Jones & Associates June 1964. Microfiche. Civil Engineering Vault. Robins Air Force Base.

Giffels & Rossetti. "Industrial Building." Drawing 35-34-01. 21 January 1959. Civil Engineering Vault. Wright-Patterson Air Force Base.

Giffels & Rossetti. "Operations Building." Drawing 30-05-01. 21 January 1959. Civil Engineering Vault. Wright-Patterson Air Force Base.

Giffels & Rossetti. "SAC Dispersal Facilities Warehouse Building." Drawing 33-02-15. 26 January 1959 (adapted for Wright-Patterson Air Force Base July 1959). Civil Engineering Vault. Wright-Patterson Air Force Base.

Samuel Glaser Associates. "Data Analysis Lab (FY-59)." Drawing 35-06-42. October 1958. Civil Engineering Vault. Hanscom Air Force Base.

Charles Goodman Associates. "Nose Docks for the C-74 and C-124." Drawing 39-05-05. 19 June 1952. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Frank Grad & Sons. Drawing for Building 1250. 1951. Civil Engineering Vault. Edwards Air Force Base.

Frank Grad & Sons. "Mess & Admin. Bldg. – Airmen. 500 Men One Story Masonry +20 Degree Zone Elevations." Drawing 36-05-63. 28 September 1951. Civil Engineering Vault. Kelly Air Force Base. Location after realignment is the Civil Engineering Vault, Lackland Air Force Base.

Graham Anderson Probst & White, Chicago. "Standard Type-Four Cell Jet Engine Test Facility." Drawing # E-100-259-003. 3 October 1951. Civil Engineering Vault. Tinker Air Force Base.

C.H. Guernsey & Co., Oklahoma City. "E-3A Maintenance Hangar." June 1986. Civil Engineering Vault. Tinker Air Force Base.

Hanscom Field. Untitled base plan. ca.1955. Civil Engineering Vault. Hanscom Air Force Base.

Hazelet & Erdal. "Radar Test Laboratory." Contract W-33-015. Eng. 1123. 31 July 1946. Civil Engineering Vault. Wright-Patterson Air Force Base.

Hazelet & Erdal. "Static Test Laboratory." (Building 20065). Contract W-1945. Eng. 382. 27 May 1943. Civil Engineering Vault. Wright-Patterson Air Force Base.

Gordon Herkenhoff & Associates. "Kirtland Air Force Base A.D.C. Facilities General Layout and Plot Plan." Drawing AF 16-07-109. January 1956. Civil Engineering Vault. Kirtland Air Force Base.

"Hill Air Force Range—Bldg Nrs 30201, 30202, 30203, 30204, 30205, 30206, 30207, & 30208 Cargo Door Repair." 31 December 1969. Civil Engineering Vault. Hill Air Force Base.

Holabird, Root & Burgee. "Operations Building for Type 4 Station." Drawing 60-02-21. 18 October 1949, site adapted for Wright-Patterson Air Force Base 6 December 1954.

Holabird, Root & Burgee. "Training Facilities. Bldg. 'GQ'." Drawing 25-04-11. 12 September 1949. Civil Engineering Vault. Kirtland Air Force Base.

Holabird, Root & Burgee. "Training Facilities. Bldg. 'O'." Drawing 60-02-21. 18 October 1949. Adapted for Kirtland Air Force Base November 1950. Civil Engineering Vault. Kirtland Air Force Base.

Holabird, Root & Burgee. "Training Facilities. Bldg. 'S'." Drawing 33-01-01. 25 August 1949. Civil Engineering Vault. Kirtland Air Force Base.

Holabird, Root & Burgee, with Farm-Rite Implement Company, Chicago. "Aircraft Service Docks Types MB1A, MB2A, MB6A, MB7A, MB8, MB11." Multiple drawings. June and November 1956. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Hoyle, Doran & Berry. "Plasma Physics Laboratory." Drawing AW 35-06-48. June 1961. Civil Engineering Vault. Hanscom Air Force Base.

Hudgins, Thompson & Ball, Inc. "Alert Facility – Buildings: Alert Crew Building." February and April 1982. Civil Engineering Vault. Tinker Air Force Base.

Hudgins, Thompson, Ball & Associates. "Armament and Electronics Building." 2 March 1953. Civil Engineering Vault. Tinker Air Force Base.

Hudgins, Thompson, Ball & Associates. "Radar Sighting System." 9 December 1953. Civil Engineering Vault. Tinker Air Force Base.

Installations Division WRAMA. "Bldg. NR. S-602." Undated. Microfiche. Civil Engineering Vault. Robins Air Force Base.

Albert Kahn, Inc. "Airplane Repair Dock Fairfield Air Depot." (Building 30206). Job 1836-A. Drawing series 6159. 9 February 1940. Civil Engineering Vault. Wright-Patterson Air Force Base.

A.M. Kinney, Inc. "Fighter Squadron Facilities Site Plan, Grading and Facilities." June 1951. Civil Engineering Vault. Wright-Patterson Air Force Base.

A.M. Kinney Inc. "Radiological Instrument Test Building." Drawing series 35-51-01. June 1952. Civil Engineering Vault. Wright-Patterson Air Force Base.

A.M. Kinney, Inc. "Research Facility—Aeronautical Laboratory." AF 35-06-21. July 1955. Civil Engineering Vault. Wright-Patterson Air Force Base.

Kistner, Wright & Wright, Los Angeles. "McClellan Air Force Base. Technical Laboratory Building." Drawing E-103-30-4. 14 September 1955. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Carl Koch & Associates. "Air Force Cambridge Research Center Fighter Facilities." 9 February 1952. Civil Engineering Vault. Hanscom Air Force Base.

L.P. Kooken. "Hill Air Force Base Special A.M.C. Warehouse, 400' by 1400'." Drawing 33-02-02. 20 May 1955. Civil Engineering Vault. Hill Air Force Base.

L.P. Kooken Co. "Special A.M.C. Warehouse." April 1952. Revised 15 October 1952 by Alexander D. Crosett & Associates for Griffiss Air Force Base Ground Electronics Storage Building. Civil Engineering Vault. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

L.P. Kooken. "Special AMC Warehouse." Drawing 33-02-58. 29 April 1952. Adapted for Robins Air Force Base 12 September 1952. Microfiche. Civil Engineering Vault. Robins Air Force Base.

L. P. Kooken Co. "Special AMC Warehouse Adapted for Tinker AFB." 29 April 1952. Civil Engineering Vault. Tinker Air Force Base.

Kuljian Corporation. "Aircraft Repair Hangar Longitudinal and Cross Sections." Drawing J-104-34-A. 3 March 1953. Civil Engineering Vault. Kelly Air Force Base. Location after realignment is the Civil Engineering Vault, Lackland Air Force Base.

Kuljian Corporation. "Hangar – Maintenance Double-Cantilever Medium Bomber AC." Drawing 39-01-44. Original date of 10 December 1951, modified for Hanscom Field September 1953. Civil Engineering Vault. Hanscom Air Force Base.

Kuljian Corporation. "Hangar Maintenance Double Cantilever Medium Bomber AC (Expanded) (No Future Expansion)." Drawing 39-01-02. 7 January 1954. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Lockheed-Georgia Company. "Nose Hangars & Misc. Buildings Industrial Area." Undated. Air Force Plant 6. Marietta, Georgia.

Lockheed-Georgia Company. "Nose Hangars No. 6, 7, 8, 9, 10, 11." 19 February 1963. Air Force Plant 6. Marietta, Georgia.

Lorenz & Williams. "Cable Repeater and Radio Relay Building." 6 August 1965. Civil Engineering Vault. Wright-Patterson Air Force Base.

Truman J. Mathews. "Readiness Room [crew dormitory]." April 1952. Civil Engineering Vault. Kirtland Air Force Base.

McDonnell Douglas. "Trestle Facility Concept Drawings in support of Annex A Facilities Design Concept (DRL A008)." Undated. Civil Engineering Vault. Kirtland Air Force Base.

"Modification of Bldg 2113 for X-Ray Facilities." October 1957. Civil Engineering Vault. Hill Air Force Base.

Neuner & Cabiness. "Administration Building." November 1952. Civil Engineering Vault. Kirtland Air Force Base.

Neuner & Cabiness. "Bomb Navigation Systems Building." April 1952. Civil Engineering Vault. Kirtland Air Force Base.

Neuner & Cabiness. "Project Engineering Building." April 1952. Civil Engineering Vault. Kirtland Air Force Base.

New Mexico Engineering Research Institute (NMERI). "Modular Storage Building. Elevations. Robins AFB Georgia [H-2 Building]." Undated. Formerly in the collection of NMERI employee Ken Bell. Donated to the Defense Threat Reduction Information Analysis Center (DTRIAC), Kirtland Air Force Base.

Joseph L. Paley. "T.A.C. Building." Drawing AW 86-16-01. 30 September 1955. Civil Engineering Vault. Hanscom Air Force Base.

Ralph M. Parsons. "Minuteman II Engineering Test Facility." Drawing 28-09-02. 12 April 1967. Civil Engineering Vault. Hill Air Force Base.

Ralph M. Parsons. "Nuclear Engineering Test Facility Engineering Test Reactor Building." Drawing AF 35-06-24. 11 April 1956. Civil Engineering Vault. Wright-Patterson Air Force Base.

Ralph M. Parsons. "WS 133A Technical Facilities Minuteman Engineering Test Facility – I Launch Control Facility." Drawing series 28-09-01. 15 December 1964. Civil Engineering Vault. Hill Air Force Base.

Ralph M. Parsons. "WS 133A Technical Facilities Minuteman Engineering Test Facility – I Launch Facility." Drawing series 28-09-01. 22 August 1962. Civil Engineering Vault. Hill Air Force Base.

Patchen & Zimmerman. "Hangar, Maintenance Shop and Supply Shop." Drawing 39-01-01. 24 November 1952. Microfiche. Civil Engineering Vault. Robins Air Force Base.

Quinton Engineers, Ltd. *Los Angeles Air Force Station*. 23 December 1964. Tab A: Narrative, and, Tab C: Basic Plans and Data. Civil Engineering Vault. Los Angeles Air Force Base.

William Radkovich Co. Inc. "Muroc Army Air Field Temporary Family Quarters." Nine drawings for Job No. Muroc AAF 7.210.2. 15 August 1947. One of these drawings may be dated 15 February ("2" not "8"). Civil Engineering Vault. Edwards Air Force Base.

William Radkovich Co. Inc. "Muroc Army Air Field Temporary Family Quarters, Floor Plan, Elevations & Details." Sheet 4. 12 May 1947. Civil Engineering Vault. Edwards Air Force Base.

William Radkovich Co. Inc. "Muroc Army Air Field Temporary Family Quarters Topography and General Layout." August 1947. Civil Engineering Vault. Edwards Air Force Base.

"Radome Testing Facility." Multiple drawings. 22 October 1956. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

"Relocate Thor Shelters." 27 February 1976. Civil Engineering Vault. Hill Air Force Base.

Roberts & Schaefer (attributed). "Hangar, Flight Test." Drawing AW 39-01-09. Multiple drawings. Earliest dates of October-December 1958. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Roberts & Schaefer. "Modification Center Type Hangars and Shop." (Building 20004). Job 4307. 2 June 1943. Civil Engineering Vault. Wright-Patterson Air Force Base.

Roberts & Schaefer. "Special Hangar with Lean-To. Signal Corps US Army." (Building 20006). Drawing series 4204. 25 March 1942. Civil Engineering Vault. Wright-Patterson Air Force Base.

"Rotor Wing Testing Facilities." Drawing 35-05-01. June 1949 and 11 July 1949. Civil Engineering Vault. Wright-Patterson Air Force Base.

"Sacramento Air Materiel Area, Miscellaneous Buildings, A.D.C. Interim Facilities." Multiple drawings. 11 May 1954 and 7 January 1955. Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Sanders & Thomas, Inc. "Science Laboratory Optics." Drawing AW 35-06-42. September 1964. Civil Engineering Vault. Wright-Patterson Air Force Base.

"Shop, Radome Test Facility, Additions." Multiple drawings. October 1968. [Buildings 667 and 662.] Civil Engineering Vault. The former McClellan Air Force Base. Location after base closure unknown.

Smith, Hinchman & Grylls Association, Inc. "School of Aviation Medicine Brooks AFB Texas Bioastronautics & Biodynamics Laboratory." Elevations and plans. Drawing 32-11-02. February 1961. Civil Engineering Vault. Brooks Air Force Base.

Smith, Hinchman & Grylls Association, Inc. "School of Aviation Medicine Brooks AFB Texas Bionucleonics Laboratory." Elevations and plans. Drawing 32-11-01. February 1961. Civil Engineering Vault. Brooks Air Force Base.

Smith, Hinchman & Grylls Association, Inc. "School of Aviation Medicine Brooks AFB Texas Biosystems Research Laboratory." Elevations and plans. Drawing 32-11-03. January 1963. Civil Engineering Vault. Brooks Air Force Base.

Smith, Hinchman & Grylls Association, Inc. "School of Aviation Medicine Brooks AFB Texas Library Building." Elevation. Drawing AW 29-04-01. February 1961. Civil Engineering Vault. Brooks Air Force Base.

Smith, Hinchman & Grylls Association, Inc. "School of Aviation Medicine Brooks AFB Texas Professional Building." Elevations and plans. Drawing AW 30-03-01. February 1961. Civil Engineering Vault. Brooks Air Force Base.

Smith, Hinchman & Grylls Association, Inc. "School of Aviation Medicine Brooks AFB Texas Site Development." February 1961. Civil Engineering Vault. Brooks Air Force Base.

Smith, Hinchman & Grylls Association, Inc. "School of Aviation Medicine Brooks AFB Texas Vivarium Support Facility." Elevations and plans. Drawing 34-08-01. February 1961. Civil Engineering Vault. Brooks Air Force Base.

Southern Engineering and Construction Co. "Dock A/C Fuel Systems." 19 May 1961. Civil Engineering Vault. Wright-Patterson Air Force Base.

Sumner Sollitt Company, with Frederick Stanton. "A Positive Ion Accelerator & Gamma Source Hot Cell." 17 July 1959. Civil Engineering Vault. Hanscom Air Force Base.

Edwin T. Steffian. "Air Force Reserve Training Center (AFRTC) Hangar A/C Maintenance & Operations." Drawing 39-04-01. Adapted from drawings by Cranshaw, Beardsley & King for identical facilities at Niagara Falls Air Force Base, New York, 11 May 1953. Civil Engineering Vault. Hanscom Air Force Base.

Edwin T. Steffian. "Readiness Building," Drawing 30-11-01. May 1954. Civil Engineering Vault. Hanscom Air Force Base.

Stevens & Wilkinson. "Aircraft Shelter Lockheed Aircraft Corp Marietta, GA." 23 April 1956. Air Force Plant 6. Marietta, Georgia.

Stewart Associates, Inc. "Geo-Physics Science Laboratory." Drawing 35-06-31. May 1957. Civil Engineering Vault. Hanscom Air Force Base.

"Storage, Depot, Rocket Assembly." Drawing 33-39-08. 3 March 1967. Civil Engineering Vault. Hill Air Force Base.

Stran Steel. "Thermal Radiation Bldg. Stran Steel Military Prefab (Katahdin Hill)." Drawing 60-09-02. 1 November 1954. Civil Engineering Vault. Hanscom Air Force Base.

Strobel & Salzman. "Hangar, Maintenance with Shops." Drawing 39-01-41. 4 June 1953, modified for Hanscom Field December 1955. Civil Engineering Vault. Hanscom Air Force Base.

Strobel & Salzman. "Hangar, Maintenance with Shops." Drawing 39-01-41. 4 June 1953. (Erected at Kirtland 1956-1957.) Civil Engineering Vault. Kirtland Air Force Base.

Sverdrup & Parcel. "Hangars, Maintenance, Engine Runup (Hush House)." 10 November 1965. Civil Engineering Vault. Hill Air Force Base.

Taylor & Gaskin. "Maintenance Docks-Type SHU-1/F Site Plan." 26 September 1958. Civil Engineering Vault. Wright-Patterson Air Force Base.

Texas Architects-Engineers Association. "School of Aviation Medicine Brooks AFB Texas Academic Building." Elevations and floor plans. Drawing 29-03-01. December 1956. Civil Engineering Vault. Brooks Air Force Base.

Texas Architects-Engineers Association. "School of Aviation Medicine Brooks AFB Texas Altitude Laboratory." Elevations and plans. Drawing 28-12-01. March 1958. Civil Engineering Vault. Brooks Air Force Base.

Texas Architects-Engineers Association. "School of Aviation Medicine Brooks AFB Texas Flight Medicine Laboratory." Elevations and floor plans. Drawing 32-39-01. December 1956. Civil Engineering Vault. Brooks Air Force Base.

Texas Architects-Engineers Association. "School of Aviation Medicine Brooks AFB Texas General Layout." December 1956. Civil Engineering Vault. Brooks Air Force Base.

Texas Architects-Engineers Association. "School of Aviation Medicine Brooks AFB Texas Heating & Cooling Plant." Elevations. Drawing 26-05-01. February 1957. Civil Engineering Vault. Brooks Air Force Base.

Texas Architects-Engineers Association. "School of Aviation Medicine Brooks AFB Texas Research Institute Building." Elevations, plans, and details. Drawing 32-11-01. February 1957. Civil Engineering Vault. Brooks Air Force Base.

Texas Architects-Engineers Association. "School of Aviation Medicine Brooks AFB Texas Research Laboratory Shops." Elevations and plans. Drawing 35-06-01. February 1957. Civil Engineering Vault. Brooks Air Force Base.

The Architects Collaborative. "Master Plan Report L.G. Hanscom Field, Bedford, Mass." ca.1959-1960. Civil Engineering Vault. Hanscom Air Force Base.

F.C. Torkelson Co. "Rocket Test Building Vertical." December 1962. Civil Engineering Vault. Hill Air Force Base.

F.C. Torkelson Co. "Rocket Test Building Horizontal." December 1962. Civil Engineering Vault. Hill Air Force Base.

J. Gordon Turnbull, Inc. "Midwest Air Depot Armament-Fire Control Supply & Repair Building." 1942. Civil Engineering Vault. Tinker Air Force Base.

J. Gordon Turnbull, Inc. "Midwest Air Depot Engine Test Building." 3 February 1942. Civil Engineering Vault. Tinker Air Force Base.

Engineering Branch. Tinker Field. "Building & Street Layout Tinker Field." ca.1943. History Office, Tinker Air Force Base.

United States Army Corps of Engineers. "E-6A Hangar." September 1989. Civil Engineering Vault. Tinker Air Force Base.

United States Army Corps of Engineers. Albuquerque District. "Training Facilities. Bldgs 'P-1 &H'." Drawing 26-05-01. November 1950. Civil Engineering Vault. Kirtland Air Force Base.

United States Army Corps of Engineers. Albuquerque District. "Training Facilities. Bldg. P-3 and Chlorinator Bldg." Drawing 26-03-01. November 1950. Civil Engineering Vault. Kirtland Air Force Base.

United States Army Corps of Engineers. Albuquerque District. "Training Facilities – Site I. Location, Building and Utilities Plan." Drawing 16-06-03. November 1950. Civil Engineering Vault. Kirtland Air Force Base.

United States Army Corps of Engineers. New England District. "Laurence G. Hanscom Field A/N Service Club NCO Club and Gymnasium Project Plan." May 1955. Civil Engineering Vault. Hanscom Air Force Base.

United States Army Corps of Engineers. New York District. "Special AMC Warehouse Completed Ground Electronic Storage Building Girder Cracks in North Bay Survey of Cracks Made 18, 19 April 1957." 23 April 1957. Civil Engineering Vault. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

United States Army Corps of Engineers. Omaha District. "Peacekeeper System Engineering Test Facility." February 1987. Civil Engineering Vault. Hill Air Force Base.

United States Engineer Office. "Bedford Air Base Electrical Distribution System Areas A and C." August 1942. Civil Engineering Vault. Hanscom Air Force Base.

United States Engineer Office. "Bedford Air Base Electrical Distribution System Area B." August 1942. Civil Engineering Vault. Hanscom Air Force Base.

United States Engineer Office. "Bedford Airdrome Drainage System." 18 September 1945. Civil Engineering Vault. Hanscom Air Force Base.

United States Engineer Office. "Building Type BEMI-AA Modified." 12 August 1943. Civil Engineering Vault. Hanscom Air Force Base.

United States Engineer Office. Binghamton District. "Air Corps Depot Rome N.Y. Illuminating Gas Distribution Schematic Plan." 31 December 1941. Storage Area, adjacent to the transitional environmental planning offices. The former Griffiss Air Force Base (in transition to the Griffiss Business and Technology Park).

United States Engineer Office. San Antonio District. "Kelly Field, Texas. Base Layout Plan." 10 April 1945. Civil Engineering Vault. Kelly Air Force Base. Location after realignment is the Civil Engineering Vault, Lackland Air Force Base.

Vitro Engineering. "A/C Lab Hi-Temp Test." Drawing E-101-250-12. 17 September 1957. Civil Engineering Vault. Wright-Patterson Air Force Base.

Weiskopf & Pickworth [adapted by Anderson-Nichols & Company]. "Rocket Storage, Checkout and Assembly Building (Unit A)." Drawing 33-39-02. May 1954. Civil Engineering Vault. Hanscom Air Force Base.

Weiskopf & Pickworth [adapted by Neuner & Cabiness]. "Walker Air Force Base Ammunition Storage & Shop Unit A Only Site Adapted for Kirtland AFB." Drawing 33-03-01. August 1954. Civil Engineering Vault. Kirtland Air Force Base.

"Wright-Patterson Air Force Base A.D.C. Facilities Rehabilitation of Existing Buildings." 1 October 1954. Civil Engineering Vault. Wright-Patterson Air Force Base.

Yonge, Look & Morrison. "Inland Nike Facilities." 1 November 1955. Civil Engineering Vault. Eglin Air Force Base.

Yosh, Nakazawa & Associates, Inc. "Science Laboratory, Avionics (AVLAB)." AW 35-06-48. July 1962. Civil Engineering Vault. Wright-Patterson Air Force Base.

Oral Interviews

Bell, Ken. Former NMERI munitions test specialist, Kirtland Air Force Base. Informal interview with Karen J. Weitze. 8 March 2000. Kirtland Air Force Base.

Billington, David P. Informal interview with Karen J. Weitze. 20 May 1999. Princeton University.

Bretz, Thomas. Distant Runner Project Manager, Kirtland Air Force Base. Informal interview with Karen J. Weitze. 10 March 2000. Kirtland Air Force Base.

Irwin, SSgt. Charles. *Base Closure and the McClellan Nuclear Radiation Center*. Interview with Dr. Wade Richards. Chief of Nuclear Licensing and Operations, Sacramento Air Logistics Center. Sacramento Air Logistics Oral History Interview #16, Air Force Materiel Command. October 1999.

Mok, Peter K. Chief Engineer, AFP 42. Informal interview with Karen J. Weitze. 4 April 2000. Air Force Plant 42. Palmdale, California.

Plamondon, Maynard A. Informal interview with Karen J. Weitze. 24 October 2000. History Office. Air Force Research Laboratory. Kirtland Air Force Base.

Smith, Terry. Range manager, UTTR. Informal interview with Karen J. Weitze. 31 October 2000. UTTR.